FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

FEUP

Multimodal Access to Social Media Services

Fernando Miguel Costa Marques da Silva Pinto

Master in Informatics and Computing Engineering

Supervisor: Maria Eduarda Silva Mendes Rodrigues
(Ph.D. and Professor at the Faculty of Engineering, University of Porto)

Second Supervisor: Miguel Sales Dias
(Ph.D., Director of Microsoft Language Development Center and Professor at ISCTE)

30th July, 2010

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Approved in oral examination by the committee:

Chair: Maria Cristina de Carvalho Alves Ribeiro (Assistant Professor)
External Examiner: António Joaquim da Silva Teixeira (Assistant Professor)
Internal Examiner: Maria Eduarda Silva Mendes Rodrigues (Assistant Professor)

26^{th} July, 2010

This work is entirely dedicated to my father - RIP (06/11/1960 - 09/03/2010).

Abstract

With only slightly more than a decade of existence, Social Media Services (SMSs) have evolved from small services used by only a few thousand people, to giant communities where millions of individuals can express their ideas, feelings and opinions on virtually any subject. Although some web-services like Facebook have made it their commitment to support impaired users, by adopting Web Accessibility guidelines, the majority of SMSs and applications that access these services are still very hard to use by mobility impaired individuals. With the growing amount of on-line presence required by current society, these kinds of digital barriers shouldn't exist, and can in turn, cause these citizens to loose contact with some people and miss valuable opportunities offered on-line.

Multimodal User Interfaces (UI) have also been studied for over thirty years by several researchers and evaluated on several use contexts, with very positive results with regards to usability improvements. To this date, however, there is no prior work on the evaluation of the use of multimodal UIs by mobility impaired individuals with Social Media Services.

This work presents the results of a series of studies conducted with mobility impaired participants. These studies supplied valuable information towards the development of a SDK for multimodal applications that access SMSs and two prototype applications, one desktop-based and one mobile-based, which allow users to interact with it through a multimodal UI. This UI gathers speech, touch, keyboard, mouse modalities on the desktop, and speech, touch and 2D gesture modalities on the mobile device.

The two prototype applications were developed based on the results of two user studies that allowed the gathering of ICT use difficulties, functional and non-functional requirements from a group of mobility impaired individuals. With these applications, a third study was conducted with participants from the other two studies, which allowed the evaluation of the prototype under controlled test situations. The results of this evaluation clearly showed that, on an initial perspective, multimodal UIs can indeed improve user activities on these services, making them not only more productive, but also more communicative, through the use of the best combination of modalities for each task, as the user believes it to be, in a seamless manner.

Resumo

Apesar de apenas pouco mais que uma década de existência, os Serviços de Média Social (SMSs), mais conhecidos pelo termo Redes Sociais, evoluíram de pequenos serviços, utilizados por poucos milhares de pessoas, para comunidades na Internet de dimensões gigantescas, algumas das quais, contando com milhões de indivíduos que exprimem diariamente as suas ideias, opiniões ou os seus sentimentos sobre praticamente qualquer assunto. Apesar de alguns *sites* como o *Facebook* suportarem normas de acessibilidade para a *Web*, a maioria dos SMSs e aplicações que acedem a estes serviços ainda não suportam qualquer tipo de normas, tornando-se bastante complexos de utilizar por indivíduos com mobilidade reduzida. Por outro lado, tendo em conta a crescente necessidade de presença *on-line* que a sociedade impõe aos seus cidadãos, seria de esperar que este tipo de barreiras digitais tivesse um impacto virtualmente nulo. Este tipo de barreiras provoca assim a info-exclusão deste tipo de cidadãos, podendo levar à perda de contacto com algumas pessoas, assim como à perda de oportunidades valiosas oferecidas *on-line*.

Por outro lado, as Interfaces Multimodais têm sido estudadas e avaliadas em contextos simulados e reais de forma exaustiva ao longo dos últimos trinta anos por vários investigadores, tendo-se verificado resultados muito positivos no que diz respeito a melhorias de usabilidade face a interfaces unimodais. No entanto, até esta data, não existe qualquer tipo de estudo que avalie a utilização de Interfaces Multimodais por indivíduos com mobilidade reduzida num contexto de utilização de Serviços de Média Social, um conceito que esta dissertação aborda.

Nesse sentido, esta dissertação apresenta os resultados de um conjunto de estudos de avaliação de usabilidade realizados com um grupo de participantes com mobilidade reduzida, nomeadamente tetraplégicos e paraplégicos. A realização destes estudos permitiu também o desenvolvimento de um conjunto de bibliotecas para o desenvolvimento de aplicações multimodais que permitam o acesso a SMSs, bem como duas aplicações experimentais, uma orientada ao *PC* e outra a dispositivos móveis *Windows Mobile*. Estas aplicações permitem ao utilizador interagir, respectivamente, através de uma Interface Multimodal que combina as modalidades de voz, toque, teclado e rato, no caso do PC, e voz, toque e gestos 2D no caso do dispositivo móvel.

Os dois protótipos descritos anteriormente foram assim desenvolvidos com base nos resultados obtidos em dois estudos com utilizadores, orientados respectivamente ao levantamento de dificuldades de utilização de Tecnologias de Informação e Comunicação (TICs), e requisitos funcionais e não funcionais de utilizadores com mobilidade reduzida.

Recorrendo a estas aplicações, foi realizado um terceiro estudo com utilizadores, com um sub-conjunto de participantes dos estudos anteriores, orientado à avaliação dos protótipos em condições de teste controladas. Os resultados desta avaliação demonstraram claramente que, numa perspectiva inicial, as Interfaces Multimodais conseguem de facto melhorar substancialmente a interacção da população alvo com este tipo de serviços, podendo-os tornar mais comunicativos, uma vez que lhes é possibilitado o uso da modalidade ou combinação de modalidades mais adequadas à realização de cada tarefa, de uma forma fluida e natural.

Acknowledgements

In the opening part of this thesis, I would like to express my sincerest gratitude to all those who somehow contributed to the success of this work. Without any specific order, this space is dedicated to all of them.

I would like to express my thanks to my supervisors Professor Eduarda Mendes Rodrigues of FEUP and Professor Miguel Sales Dias of MLDC who, despite all the difficulties and the significant amount of work ahead of me, always supported and encouraged me during all this process, providing vital suggestions for the completion of this work.

To António Calado, João Freitas and Pedro Silva, of the MLDC development team, for all their support during the development and testing stages of the prototype SDK and application.

To Ana Judice, Daan Baldewijn and Difda Monterde for all the valuable input they supplied during the development and testing stages of the prototype.

To Marta Castanheira, Nuno Costa and Tiago Barbosa for all the valuable feedback regarding design improvements on the final prototype.

To all the mobility impaired participants from Associação Salvador without whom it would have been impossible to conduct this thorough study.

A special thank you to Salvador Mendes de Almeida, founder of Associação Salvador, for all his support towards this work, and for mediating the recruitment of the study participants and the scheduling of the study sessions.

And at last, but not least, I want to express my gratitude to my family who were always by my side, supporting me during all the difficult times. Thank you very much!

Fernando Miguel Costa Marques da Silva Pinto

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Abbreviations

3D	Three Dimensional
AAL	Ambient Assisted Living
API	Application Programming Interface
ARPANET	Advanced Research Projects Agency Network
ASR	Automatic Speech Recognition
BBS	Bulletin Board System
CAPTCHA	Completely Automated Public Turing test to tell Computers and Humans Apart
CLI	Command Line Interface
CSS	Cascading Style Sheets
E.U.	European Union
FBJS	Facebook JavaScript
FBML	Facebook Markup Language
FEUP	Faculdade de Engenharia da Universidade do Porto
FP	Framework Programme
FQL	Facebook Query Language
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Human-computer Interaction
HTML	Hyper Text Markup Language
ICT	Information and communication technology
IR	Infra-red
IRC	Internet Relay Chat
I/O	Input/Output
IT	Information Technology
LED	Light Emitting Diode
JSON	JavaScript Object Notation
HMM	Hidden Markov Model
MLDC	Microsoft Language Development Center
MMUI	MultiModal User Interface
N/R	Did not Reply
OS	Operating System
PC	Personal Computer
PDA	Personal Digital Assistant
RDBMS	Relational Database Management System
REST	Representational State Transfer
RSI	Repetitive Stress Injury
RSS	Really Simple Syndication

ABBREVIATIONS

RSVP	Répondez s'il vous plaît
SDK	Software Development Kit
SNS	Social Network Site
SOAP	Simple Object Access Protocol
TTS	Text-To-Speech synthesis
UCD	User-Centered Design
UI	User Interface
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
WIMP	Window, Icon, Menu, Pointing device
WPF	Windows Presentation Foundation
XFBML	eXtensible Facebook Markup Language
XHTML	eXtensible Hyper Text Markup Language
XML	eXtensible Markup Language

Chapter 1

Introduction

From the very beginning mankind has had an inherent need to communicate, be it directly or indirectly. Starting with cavemen and their crude but effective vocal and gesture based direct communication methods, as well as pictographs drawn on caves [McF05]. Over the centuries existing communication methods have evolved, with new languages and dialects being developed by mankind. However, many new communication methods were also created, be it letter writing, made possible by the invention of paper in AD 105 [Mus06b], or even the telephone, patented by Alexander Graham Bell in 1876, who also started commercial usage as a means of communication in 1878 [T08].

The electronics revolution, initiated by the mass production of transistor based devices in the second half of the 20th century, along with the invention and evolution of microprocessors over the past 30 years allowed the creation of smaller and more powerful devices such as desktop computers, notebooks, cellphones, and more recently smartphones and netbooks. These technological advances, along with the creation of the Advanced Research Projects Agency Network (ARPANET) in the 1970's [Mus06a] which later became the Internet as we know it today, paved the way towards the development of new communication methods such as E-mail [BPTW73, Pos82] in the 1970's and 1980's or Bulletin Board Systems (BBSs) in the 1980's and early 1990's [Gor01].

During the 1990's and 2000's, the rise of the always-on society paradigm [Res08], fuelled by cheap internet access and smaller, more powerful devices, led to the development of new internet based instant communication technologies. Internet Relay Chat (IRC) [OR93], one of the earliest instant messaging protocols, allows a user to communicate with other users around the world almost without any delay. With this new paradigm in hand, more advanced applications have been developed over the past two decades, making it possible not only to exchange messages, but also to transfer files, and even audio and video chat.

The new millennium also brought new ways of not only on-line communication but also socialization. Blogs allow common users to share their thoughts with the world, and social media sites make it possible for people not only to find new people on-line, but also to maintain existing "real world" relationships, thus allowing a new level of on-line interaction [BE07].

1.1 Context and Scope

Although some Social Media Sites exist for almost a decade [BE07], and Web Accessibility guidelines have been defined and improved by the World Wide Web Consortium (W3C) for over ten years [Wor10b], many of these sites still don't follow these guidelines.

Technological aspects, mostly related with Web 2.0, such as Dynamic pages, Completely Automated Public Turing tests to tell Computers and Humans Apart (CAPTCHAs), among others, create an entry barrier for users who depend on accessibility devices such as mobility impaired users. On the other hand most applications used to access social media sites, either on a desktop or on a mobile device, aren't developed with disabled users in mind. Besides these factors, some knowledge of how the internet works or at least some computer knowledge is required of social media sites' users, which creates an entry barrier for users who haven't had too much contact during their lives with information technology (IT).

Considering these limitations, mostly on the desktop and mobile devices domains, it's easy to see the need for new solutions that can minimize the existing entry barriers for mobility impaired users. There is thus an opportunity for the development of simplified social media interaction applications. Whether the usage of multiple input and output modalities can indeed allow a more seamless and natural interaction with social media sites by such kind of users, in accordance to their preferences and limitations, is something that still hasn't been thoroughly explored.

1.1.1 Research Context

This dissertation work was developed in cooperation with the Microsoft Language Development Center (MLDC) located in the Portuguese subsidiary of Microsoft, in Porto Salvo, Oeiras, which supported this dissertation under QREN Living Usability Lab (LUL) [MCdA10].

Approximately nine weeks were spent at the center's installations in Porto Salvo, entirely dedicated to the specification, development and elaboration of a prototype, a scientific paper and a usability evaluation study with a group of mobility impaired individuals.

This work was thus developed under a larger usability enhancement initiative and as such, some aspects of this work were developed in collaboration with the author of [dNTGP]. As such, the user studies of both thesis' were designed collaboratively, however, the parts specific to each dissertation were designed and analysed individually. To allow a more seamless experience to the end user, each dissertation author developed his own components, as he believed were adequate towards his work, however, these components were constantly integrated under the same SDK and proof-of-concept applications.

1.2 Motivation and Goals

Although some advances have been made regarding accessibility in social media services, most desktop and mobile social media applications still can't be fully used by mobility impaired citizens. This, coupled with the existence of case studies regarding the usage of multimodal interfaces with these audiences, most of which reveal positive results, can be considered as encouraging factors towards this study. Thus, the main motivation of this thesis is to study whether a more user friendly interface can help with the adoption of IT and promote increased participation in the electronic society by a group of mobility impaired users, therefore contributing to the electronic inclusion of these people. The main purpose of this dissertation is the study of how the application of several forms of input and output modalities can enhance the user experience in accessing and contributing to social media services by mobility impaired individuals, by improving perceived usability on these kinds of services. Therefore, this work follows this list of specific objectives:

- Assess state-of-the-art contributions regarding usage of computer interfaces and social media services by the study participants, and the main problems detected by these users, as well as current multimodal interface usage in accessibility contexts, and their advantages and disadvantages.
- Examine, by direct contact with the study participants, if the results obtained in the state-of-the-art assessment are translatable to mobility impaired users, and which additional problems exist.
- Develop a Software Development Kit (SDK) that allows the easy development of multimodal interface based applications, integrating several social media services in a seamless manner.
- Develop a proof-of-concept application with the SDK and evaluate it in a controlled user study.

1.3 Dissertation Outline

This dissertation is divided into 8 chapters and includes 6 appendices.

This first chapter focuses on the definition of the context, scope and expected outcome of this dissertation work.

Chapter 2 expands the initial context and supplies an in-depth analysis into the state of the art in the areas of mobility impairment limitations in both the real and virtual worlds, as well as current and past initiatives focusing on e-inclusion. This chapter also analyses past and current concepts and developments in the areas of hardware user interfaces and multimodal user interfaces. The final sections review some requirements gathering and usability evaluation methods.

Chapter 3 presents the results of the two preliminary user requirements gathering sessions, concluding with some usability recommendations for the development of social media applications that are easy to use by mobility impaired individuals, specifically paraplegic and quadriplegic individuals.

Chapters 4, 5 and 6 provide an in-depth look into the actual prototype developed, respectively focusing on the functional and non-functional requirements, architectural and technical aspects of the SDK, including which SMS APIs were used, and prototype proof-of-concept applications that were developed, the latter detailing the UI development evolution, choices and followed standards.

Chapter 7 presents the results of the user study conducted to evaluate prototype usability, in a controlled environment, by a panel of mobility impaired participants who collaborated throughout this whole work.

Chapter 8, draws the general conclusions from the entirety of this dissertation work. Some notes and recommendations for future work are also given.

Appendix A presents the questionnaires used for requirements gathering and the responses from participants.
Appendix B contains an extended list of functional requirements derived from the requirements gathering sessions' results.
Appendix C contains the remainder of mockup screens produced during the specification stages.
Appendices D and E respectively contain detailed prototype screenshots and extended descriptions of additional Social Media Services' APIs that were considered as for deployment in the final prototype.
Appendix F extends the content of Chapter 7, by presenting user comments and other detailed data gathered during the final prototype evaluation session.

Chapter 2

State of The Art

Currently there is an ever growing amount of social media services and accompanying applications, each with their own specific domains.

Depending on the device where these applications are installed, several types of user interfaces can be used to enhance the user experience. On the subject of user interfaces, many scientific contributions have been made over the past twenty years, focused on several areas of relevance to the study at hand.

Although there have been many publications studying the usage of unimodal and multimodal User Interfaces (UIs) by elderly users and by mobility impaired users, to the writing of this thesis, no articles have been published regarding the usage of a multimodal UI, by mobility impaired users, that allows an easier access to social media services.

This chapter provides an insight onto some of the concepts related with this field of work, initiatives launched to fight e-exclusion, as well as some contributions to the user interface area, mostly focused on accessibility. Also included in this chapter is an overview of some Human-computer Interaction (HCI) methods to be used throughout the thesis as well as a critical analysis of which technologies exist that can be used in this work.

2.1 Social Media Services

A social media service (SMS) is defined by Boyd in [BE07] as a web service that allows an individual to:

- Construct a public or semi-public profile in the site
- Maintain a list of users with whom he/she shares a connection or interest
- View and traverse their own list of users and those made by other users within the site

Over time however, SMSs have evolved beyond these fundamental features, with sites now allowing content upload such as photos, videos, as well as hosting small applications

[Joi08]. SMSs such as Reddit or Digg focus on a different concept called social news, allowing not only the previously mentioned concepts, but also the publishing of stories and links, which can then be voted by users, thus allowing them to control how popular a story or a link is [Inc09f, Dig10].

2.1.1 Brief History

Although the first recognizable SMS was only launched a decade ago (SixDegrees.com in 1997), this phenomenon has had a massive growth in a very short time span. Since then social media services have gone through many evolutions.

The rise and fall of Friendster popularity (2002-2005), gave way to mainstream support by large corporations of SMSs [BE07]. By 2005 the acquisition of MySpace by News Corporation and the launch of Yahoo! 360,° by Yahoo marked the beginning of a new stage in SMS usage, main-streaming.

Since then, many social media services have lost popularity (MySpace, Pownce, etc) while others have risen, gathering both users of other SMSs as well as new users, with social media sites such as Facebook or Twitter surpassing respectively 400 million [Fac10a] and 6 million users [Zar09].

The rise and fall of some SMSs and current main-streaming of SMSs can been seen in Figure 2.1

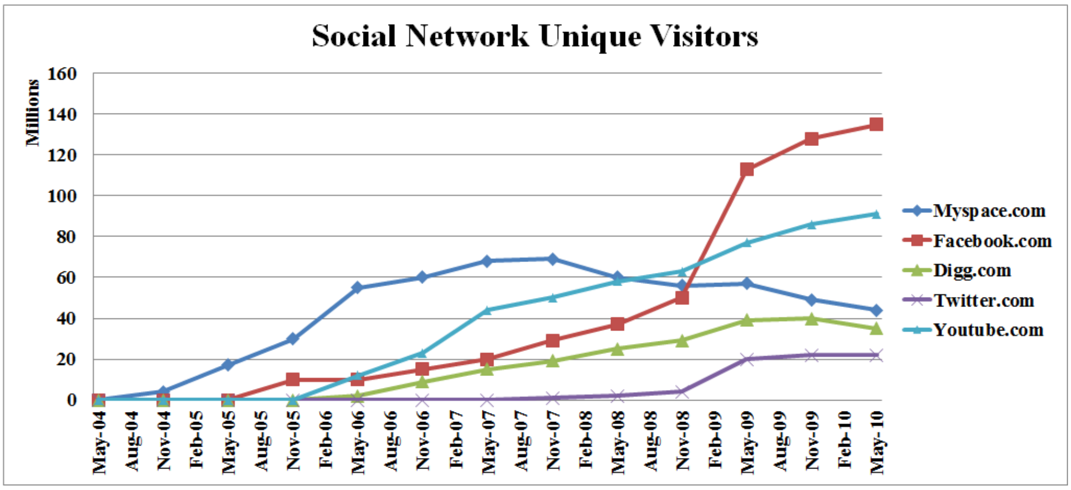


Figure 2.1: Social Media Sites' unique visitor count throughout the time (Source [Inc10b])

Currently, social media sites are available in several domains such as music (Last.fm), micro-blogging (Twitter, Jaiku), books (ANobii), photos (Flickr), professional networking (LinkedIn). Some SMSs are also mostly focused on specific geographical locations, with sites such as Friendster having a large user base in Asia [AI10a], Orkut mostly focused in Brazil [AI10c] and hi5 in Latin countries such as Portugal or Peru [AI10b].

2.1.2 Usages

Social media sites have typically been used by individuals as a way to connect and communicate with people who are already part of their *extended social network*, be it through work, school/university or casual acquaintance, using the above mentioned features such as profiles and connected users' lists [BE07]. Although, as pointed out in [BE07, Joi08], this is usually the main usage individuals give to SMSs. A small percentage also uses them to meet new people, with the purpose of on-line or off-line interaction, be it on a casual level as with Facebook [Joi08], or on a professional level, as with LinkedIn [Lin09].

Social media services such as Flickr, YouTube or Last.fm, allow the development of a new follower trend, under which the sites' users have the ability to follow other users based on which content they post, be it simple messages, photos, videos or even events or musical preferences such as with Last.fm [Ltd08a].

Microblogging enabled sites such as Twitter, Jaiku, Pownce and Facebook, allow individuals to send short text messages to other users of the service, mostly about small events in their daily life such as what they're reading, thinking and experiencing. Other usages of these services focus on public opinion querying towards other users on various subjects, knowledge seeking or even interest sharing. These services can thus provide individuals "another layer of connection with friends and the world" [ZR09]. Many factors during 2008 contributed to the mainstream adoption of Twitter as a de-facto standard for Microblogging tools during 2009. Among these were the 2008 Mumbai attacks eyewitness coverage and the publicity efforts during the 2008 U.S. presidential campaign [Row08]. This led the way towards mass adoption of Twitter as a means to receive the latest updates on many news sites, as a way to follow celebrities and as a way to bypass censorship such as during the 2009 Iranian presidential election [Inc09a].

2.2 Study Participants

Mobility impaired individuals are defined in the literature as those whose disabilities "affect the ability to move, manipulate objects, and interact with the physical world" [Den01].

Some of the main physical limitations these individuals face are [Den01]:

- Partial or total loss of muscle control
- Muscle weakness
- Motor coordination issues
- Involuntary or uncontrolled motion
- Movement limitations

These limitations can result from genetic abnormalities, accidents or excessive muscle strain, and can severely limit Information and Communication Technologies (ICTs) usage by these individuals, with issues ranging from inability to use a mouse, since they require coordinated movements, text entry via keyboard, as well as voice input when the user has problems controlling face muscles [Den01].

Participants in this thesis's studies belong to one of two specific mobility impaired individual groups: quadriplegic or paraplegic individuals. Both these impairments relate to spinal cord injuries, with the applied classification of paraplegia or quadriplegia depending on the "level and severity of the a person's paralysis" [App10b]. As such, a person is considered a quadriplegic his/her spinal cord injury is located "above the first thoracic vertebra", resulting in "paralysis of all four limbs", more specifically, complete paralysis of the legs as well as partial or complete paralysis of the arms, depending also on the severity of sustained injury [App10a]. A person is considered a paraplegic when he/she has a spinal cord injury located "below the first thoracic spinal nerve", and as such, has a lower impairment level than a quadriplegic person, with paralysis ranging from "impairment of leg movement, to complete paralysis of the legs and abdomen up to the chest line". Paraplegics thus, have no issues using their arms and hands [App10c].

Just as with elderly citizens, social relations established with motor impaired individuals can be considered very important for the maintenance of physical and psychological health, protecting against issues such as cognitive decline [WBP+09]. The inability to have an independent life, which is a major issue for some motor impaired individuals, can lead to reduced social interaction, causing isolation, which can then breed loneliness. These situations, as some studies have shown, can cause depression, which can then easily lead towards lower quality of life and even death [Din06].

ICTs have previously been used to enhance social interaction between motor impaired individuals and other people, while also providing easier access to information and on-line services [GJ07, MVIH02]. These studies, however, focused on improving accessibility for mobility impaired individuals and elderly individuals on a web site usability perspective, which differs from this work's approach.

2.2.1 e-Inclusion

Even though throughout history, ICT accessibility factors have, most of the time, been considered frivolous aspects, some initiatives have been taken over the past 30 years to enhance impaired users' quality of life.

The official definition of terms "disability", "impairment" and "handicap" in mid-1970's by the World Health Organization, brought these issues, up till then considered not so relevant, into focus, prompting the development of disability policy during the 1980's. Despite the development of ICTs during the 1980's, and related input and output technologies, most companies didn't focus on the development of assistive technologies until the late 1980's. By then however, most assistive technologies such as screen readers were only compatible with text based interfaces [HM06]. The development and mainstreaming of Graphical User Interfaces by this time led once again to impaired users being left out of the latest technological advances, with the first Graphical User Interface (GUI) compatible screen reader prototype only being developed in 1990 [Sch91]. The advent of the internet also brought some of these problems. Although accessibility guidelines have been defined for over 10 years [Wor10b], most web sites don't bother to follow them for several reasons [Den01].

Since 2000 however, several initiatives have been launched by the European Union with the intent of building a more connected and accessibility friendly Europe, ready for the "knowledge based economy" of the twenty first century [iAEISfge09].

Action plans such as eEurope 2002 [iAEISfge09], eEurope 2005 [iAEISfge09], and more recently i2010, the latter launched in 2007, have focused on progressively improving connectivity and IT integration throughout Europe.

Starting with eEurope 2005, and continued with the current i2010 initiative, greater interest has been given to bringing the benefits of the Information Society towards the socially excluded and people with special needs. As such, parallel initiatives like eInclusion@EU [eIn04b], the Ambient Assisted Living (AAL) Joint Programme [Pro10] and the i2010's eAccessibility initiative [Com10b] were launched with the purpose of supporting Information Society policy-making in the European Union (E.U.), focusing on accessibility and inclusion aspects, as well as the development of Assisted Living technologies aimed at improving the lives of elderly and mobility impaired people in Europe.

From these initiatives resulted several events promoting eInclusion and eAccessibility topics in areas such as education, medicine, smart homes [eIn04a], as well as reports with recommendations for future actions to be taken on E.U. policy level [eIn04b] to ensure disabled and elderly people can access ICTs as easily as regular citizens, thus removing technological barriers that may exist while accessing products, services or applications.

Currently several projects have already been launched under these Programmes, having produced some results [Com10c]. These include *AGeing in a NEtworked Society* (AGNES) [WBP+09], which aims to connect elderly people living at home with their families, friends and carers, or *PERceptive Spaces prOmoting iNdependent Aging* (PERSONA) and *Service-Oriented Programmable Smart Environments for Older Europeans* (SOPRANO), both of which are aimed at developing affordable, smart and easy to use ICT-based AAL services for older people [Mar10, SA10].

Although some of the projects under development in the areas of eAccessibility, eInclusion and AAL are geared towards senior citizens, most of the results obtained on areas such as limited/reduced mobility in that particular audience can be considered useful regarding this thesis' target audience (i.e. mobility impaired users), since most of the limitations expressed by senior citizens regarding limited motion are shared by the target audience.

2.3 Human Computer Interfaces

A Human Computer Interface can be defined as a set of artefacts with which people can interact with a machine, typically software running on a computer. These artefacts can be of one of three types: Input, Output or Mixed (Input/Output), respectively providing information to the computer, thus allowing a user to manipulate the system, providing information to the user, thus allowing the system to send feedback to the user, or a mix of both.

Although some user interfaces from the Batch computing era allowed the user some interaction with a computer, through punch cards, real-time user interfaces as we know them today only became possible in the late 1960's, and popularized in the 1970's and beginning of the 1980's with the development of Command Line Interfaces (CLI).

Most CLIs use keyboards as an input method and a computer screen as an output method, although some, depending on the software being used, allow some rudimentary graphical interaction with a mouse.

Inspired by Doug Engelbart's work in the 1960's on the mouse and graphical human interface methods, engineers at Xerox PARC developed what is considered the first system with a GUI, exploring concepts still used in modern GUIs such as the desktop metaphor and the Window, Icon, Menu, Pointing device (WIMP) paradigm. These developments were, however, only adopted later as components of a true commercial Operating System (OS) with the launch of the Macintosh in 1984 and later Microsoft's Windows OS [RL04].

Although GUIs are still used today as the main type of UI, new paradigms such as Web-based interfaces have been built on top of the GUI, allowing the exploitation of newer approaches to content visualization through the display of dynamic content. Input and output methods have also evolved beyond the typical mouse and keyboard peripherals, to encompass more natural ways of interacting with the computer. Some of the more main-stream are:

- Handwrite recognition interfaces
- Touch interfaces
- Voice interfaces

Besides these, other types of interfaces are currently being developed also with the intent of providing a more natural interaction with technology. Included in this list are:

- Gesture recognition interfaces
- Gaze interfaces
- Brain-computer interfaces

The development of these types of interfaces allows an easier adoption of newer technologies by users with limited levels of computer skills, as well as those with mobility impairments, such as this study's participants.

The following sections analyse some of the most common of these interfaces and their state-of-the-art.

2.3.1 Touch Interfaces

The term *touch interface* can be used to describe several types of computer interfaces. In this thesis, this term will be used to describe interfaces commonly known as touch screens. It should also be noted that the term *gestures* as used in this section refers to finger gestures expressed on a two dimensional surface such as a touch screen.

Although touch screens have been available since the 1980's, most of these were used either in a research context or, when available commercially, used in kiosk devices [PWS88]. Nonetheless, the first portable commercial touch screen powered devices were only available by the 1990's with the launch of Personal Digital Assistants (PDAs) by Apple (Newton) [Hor06], Palm (Pilot) [Roy05] and later Windows CE and Windows Mobile powered devices [Hal06]. These devices however, allowed only single finger interaction or through a stylus, commonly called *screen tapping*, which made it possible to enter text, via a virtual keyboard on the screen, or via handwrite recognition, using the stylus.

Tablet devices, allowing more natural user input, have been around since the 1960's, with one of the first known examples being the RAND tablet [Cor98]. These early devices have since then evolved through the 1980's to the concept known today as tablet Personal Computers (PCs). These devices allow direct interaction on a screen instead of on a separate device [MOR+88]. Although the first commercial tablet PC devices were made available in late 2002, these also only allowed interaction with a single finger or through a stylus, thus limiting possible user interaction [Thu02].

The launch of Apple's iPhone in 2007 marked the main-streaming of a new touch interface concept, multi-touch screens. This technology allows the user to interact with a device using multiple fingers simultaneously, thus creating more natural gestures on the screen, which are then associated by the device to specific functions. This concept, however, has already been under development since 1982 [Bux09], with some early commercial multi-touch capable devices dating back to at least 2001 [Fin01]. Currently many devices exist with multi-touch screens, ranging from the several iterations of Apple's iPhone, and some Android powered smartphones [Web09], to some tablet PCs running Windows 7, and Microsoft's Surface [Cor09d].

Touch interfaces, allowing some gesture recognition, have been used in projects to increase accessibility, achieving very positive results due to the flexibility of this means of interaction. Some examples include Navtouch [GLN+08] and Google's Eyes-free project [Cha09b], which both allow blind users to input text on a mobile device using navigational gestures, without the need for expensive, specifically oriented accessibility solutions.

2.3.1.1 Advantages and Issues

Some of the advantages of touch interfaces range from the ability to have a more natural interaction with devices, to faster interaction with the system, due to the usage of gesture commands and, in case of touch screens, the input and output device being the same [Nam00].

The development of these devices and their software must, however, take into account some factors which differentiate them from regular Input/Output (I/O) devices, such as the common keyboard, mouse, and monitor combination.

Ergonomics related issues must be taken into account such as avoiding displaying small items on screen, which may be difficult to select by the user, distance between the user and the screen, and possible arm fatigue, thus avoiding classic issues such as *Gorilla-arm* [Saf09].

2.3.2 Voice Interfaces

Voice interfaces, also known as speech interfaces, allow an individual to interact with a computer system through regular speech. Just as with regular speech interaction between humans, two different types of actions exist during speech interaction with a computer: Automatic Speech Recognition (ASR), more commonly known as speech recognition, and Text-To-Speech synthesis (TTS), more commonly known as speech synthesis.

Speech, as a more natural way to communicate, has been under development on computer systems since the late 1950's and 1960's [Shu58, BMMS66].

Although still not perfect, over time, issues such as speech intelligibility, naturalness, flow, accent, syntax and semantics have been improved in both ASR and TTS systems, with current systems boasting high efficiency rates in optimal conditions, depending thus on the level of environmental noise or system voice training. More computationally powerful systems as well as more elaborate algorithms have significantly contributed towards these improvements.

Currently, voice interfaces are integrated into many everyday electronic components, offering features that range from controlling an OS through speech recognition, and text reading, supported on Windows 7 [Cor09c], Mac OS X [Inc10a] or Linux [Shm09], and hands-free device interaction in a vehicle with Ford Sync [Com09] or on Global Positioning System (GPS) devices [Cha09a, Por08].

One of the most important domains to which voice interfaces have contributed over time, is in supporting better integration of users who, by several reasons, cannot use regular interaction methods such as keyboards and mice, therefore allowing them to use technologies, just as easily as anyone without a disability. Several applications, from screen readers to voice communications applications [CL08] exist, that can help users with disabilities ranging from blindness [Cha09b] and Repetitive Stress Injuries (RSI) to mobility impairments and cerebral palsy.

2.3.2.1 Advantages and Issues

Voice interfaces can help users have better interactions with technologies, regardless of being handicapped or not. They allow speedy, high-bandwidth content input and relative easy system interaction. They also allow users to keep their hands and eyes concentrated on one task while using speech to control a device [OCW+00].

However, even with speech systems as evolved as today's, some considerations must still be taken into account. The accent with which sentences are spoken as well as mechanical voices are two issues that still drive many users away from voice interfaces, as the voice interaction doesn't sound very natural.

Technical issues such as available processing power, amount of word recognition errors in speech recognition processes must be taken into consideration while developing these types of interfaces [FZHS08]. Some of these issues can be solved by using backend speech processing solutions, thus significantly reducing the burden on Central Processing Unit (CPU) usage in mobile devices, while also allowing more powerful algorithms to be used. This, however, comes at the expense of not having real-time speech processing, which becomes dependent on several factors such as backend processing load issues, network latency, among others. Language scope is yet another possible way of reducing the impact of some of these issues. By reducing the accepted language from a full natural approach to a somewhat limited simulated syntax scope, using context specific grammars, it's possible to both reduce the length of time it takes to develop a speech based application, as well as reducing the processing power needed to employ some of these speech techniques [RR00].

2.3.3 Gestures Interfaces

Three dimensional gesture interfaces are used as more natural ways of interacting with computer systems, usually through the interpretation/recognition of human gestures originating from facial expressions or hand gestures. These types of interfaces make it possible to explore the potential of human body language, thus allowing a more expressive way of communicating with computers. Due to the very expressive nature of gestural interfaces and the multitude of gestures that can be elaborated, probability based techniques such as Hidden Markov Models (HMM) have to be used to better interpret the meaning of these gestures.

Gesture recognition interfaces have been developed and evolving over the past 30 years, with the first published example of this type of interface being Richard A. Bolt's

Put That There prototype, in 1980. This system used gestures, more specifically pointing, as a way to tell the system where actions, input through speech, should be applied [Bol80].

Towards the end of the 1980's, new gesture based devices started showing up. These however, required the user to wear a glove fitted with sensors. Although some were created as proof-of-concept devices, such as the Z-Glove and DataGlove (see Figure 2.2), these still allowed the user a more powerful experience than that offered by previous hand gesture interfaces, such as real-time manipulation of 3-dimensional objects represented on a computer screen [ZLB+87]. Some commercial applications of this type of peripheral were also developed, such as the Power Glove, compatible with late 1980's Nintendo systems, or the CyberGlove [LLC09]. Although the CyberGlove and DataGlove both allowed capturing of high resolution and precise motion, the Power Glove, since it was targeted at a more main-stream audience, had many technical issues, mainly caused by use of inexpensive components [Tow94], which led to it being rated as one of the worst game controllers ever made [Har06].

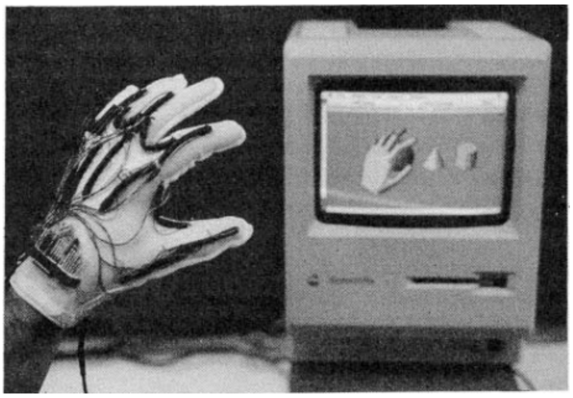


Figure 2.2: The DataGlove Gesture Recognition hardware and software (Source [ZLB+87])

Currently, the Wii-controller, also known as the Wiimote, is considered one of the most common and advanced devices capable of recognizing some hand gestures. To accomplish this, the Wiimote uses a built-in accelerometer, allowing it to recognize three dimensional (3D) hand-motion, as well as an Infra-Red (IR) emitting device called a Sensor Bar (see Figure 2.3), which is used by the Wiimote to measure the distance at which it is located from the visual interface (usually a TV screen or a computer monitor), allowing a more precise interaction with the virtual environment being used [Dev06]. Some effort has also been done with this device, so as to provide more accurate and user-customizable gesture recognition software, thus allowing the usage of the Wiimote in more generic applications [SPHB08].

Some novel technologies are currently under development such as Microsoft's Kinect, which allows full-body 3D motion capture as well as facial recognition [Met09], or MIT

Figure 2.3: The Wii Remote and Sensor Bar (Source [Wik10])

Media Lab's BiDi screen, which allows interaction with devices, similar to that idealized in Minority Report [HLHR09].

A different kind of gesture recognition interface, based on the detection of human muscle movement in real-time through the use of forearm electromyography (EMG), has been tested with positive results, thus allowing gesture recognition in situations where conventional hand gesture recognition wouldn't be very easy to use [STM+09].

These advances will most likely lead to main-stream production and adoption of gesture recognition based interfaces, allowing cheaper and more powerful interfaces to be developed and used in the future, for diverse domain applications, including AAL.

2.3.3.1 Advantages and Issues

Gesture recognition interfaces offer many advantages when compared with more standard input devices such as keyboards and mice. Among these are ease of use by users with motor impairments, requiring less dexterity, as well as allowing a more interactive and immersive operation of multimedia applications such as games.

Some technical limitations must also be taken into account, such as accuracy of gesture recognition technologies being used. Microsoft's Project Natal for instance, due to having its recognition hardware slightly offset from the display, cannot be properly used at short distances [Sav09]. Issues like hardware sensitivity, image noise, environmental lighting or background items, also make gesture recognition more difficult to accomplish.

2.3.4 Gaze Interfaces

Gaze interfaces are a set of UIs more commonly used by individuals with severe motor impairments. These interfaces essentially do eye tracking, and can either be worn by the subject in, for example, a helmet, with the disadvantage of sometimes being considered too intrusive, or can be placed at a certain distance from the subject.

Regardless of the interface's placement, two kinds of technologies can be used to track the subject's eye: Infra-red (IR) light and appearance based systems [JS07]. In the first type, an IR light is pointed towards the subject's eye, and the resulting red-eye effect is used to track the sight's orientation. Appearance-based interfaces use images photographed by a computer's camera, and apply computer vision algorithms to track the eye and its orientation in the images [JS07].

2.3.4.1 Advantages and Issues

One of the main advantages of gaze interfaces is that they can be used by users with severe impairments that prevent them from operating any other type of interfaces.

However, as noted in [JS07], there are some issues with these types of interfaces that must be taken into consideration. While wearable interfaces are considered more accurate in capturing the eye's movement, their intrusiveness can be uncomfortable to the user. On the other hand, non-wearable systems require personalized calibration for each user, which can take quite some time. IR based systems, however, have not yet been considered completely safe, as the long term effects of exposure to IR are still unknown. Also, issues can arise from the usage of low image resolution in two camera appearance-based systems, as they can reduce the accuracy of this method.

2.3.5 Multimodal Interfaces

Several definitions exist as to what a multimodal interface is, depending on the context.

A more technical definition, given by Johnston in [JB05], states that a multimodal interface is a system which allows input and/or output on multiple types of channels, be it speech, gestures, graphics, among others, thus allowing users to choose which modalities are better suited to their needs, enabling a more natural and effective interaction with the system.

Another, more human-centered definition, states that a multimodal interface is a system that responds to inputs in more than one modality, being that a modality is seen as a means of communication matching a human sense, such as cameras, microphones, haptic sensors, matching respectively, sight, hearing and touch. Other devices used that don't directly match any sense, however, are also considered in this definition, such as keyboard, mouse, tablet, among others [JS07].

Nonetheless, a more concise definition is simply that a multimodal interface is one that allows an individual to interact with a system through more than one type of I/O device, allowing the user to choose which modalities are more adequate to them, which can depend on factors such as user disabilities, preferences or proficiency with a certain modality [Ovi01].

2.3.5.1 Architecture

Considered the first true multimodal interaction system, Richard Bolt's *Put That There* [Bol80] work, combined speech as a main modality, which allowed a user to specify system commands, with three-dimensional gestures, allowing a user to specify where the action should be applied. This work was not only the first of its kind, but also specified a system architecture and concepts that are still used today as the cornerstone of multimodal interaction systems. A graphical representation of this architecture can be seen in Figure 2.4

A multimodal interaction system is composed by input and output devices, their respective recognizers and a group of integration subcomponents, called an integration committee.

The input recognizers are responsible for perceiving the input, and outputting an associated meaning, similar to a semantic processor.

The integration committee is composed of a fusion engine, a fission module, a dialog manager and a context manager. When the input recognizers generate valid outputs, these are sent to the fusion engine, which uses them to extract the composed meaning of the user's actions towards the system. This meaning is then sent to the dialog manager, in charge of activating events in applications waiting for user input.

The opposite process also happens, with the dialog manager receiving messages from the applications, which are then sent to a fission engine, in charge of returning the message to the user through the most adequate modality or combination of modalities.

Since different users may prefer to use different I/O modalities, a fourth component exists in the integration committee, called a context manager. This component records user profiles as well as modality usage context, and thus, communicates these preferences to the remaining three components, so they can better adapt their actions to users' preferences [DIL09].

Since the first systems, many advances have been made concerning multimodal fusion and fission algorithms, modality disambiguation, as well as usable input and output modalities, the latter mainly due to technological advances [LNP+09].

2.3.5.2 Multimodal Fusion

As further elaborated in [LNP+09], multimodal input fusion can be done in several ways, with varying advantages and disadvantages. Modalities can be processed sequentially or in parallel, and the output of modality processing can be either combined or used independently. Independent modality processing can be useful if applications using this

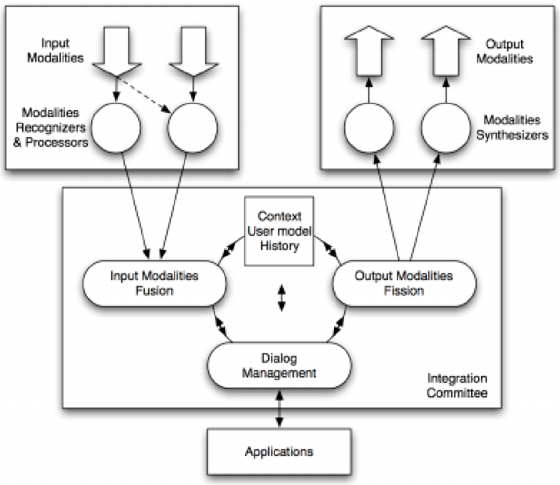


Figure 2.4: The architecture of a multimodal system (Source [DIL09])

architecture need lower level information regarding the user's input. Modality semantic content combination at the fusion engine level however, allows better abstraction and the addition of other modalities without modifying upper level components in the application's architecture, but there may not be enough information needed by upper levels in the architectural model of the application, and modality disambiguation is more difficult to handle.

Regarding sequential and parallel modality processing, a parallel model is better suited for situations where input data redundancy is important, however, modality synchronization, through timing mechanisms, must be taken into account, so as to avoid wrong interpretations of user input. Sequential modality processing allows the development of simpler fusion algorithms, without a critical need for input synchronization, however, it won't be possible to correctly process simultaneous events generated by the user, as semantic interpretation is done individually to each event [LNP+09].

Fusion techniques have evolved through many stages, ranging from simple modality fusion when events need to be generated in the application, sequential approaches in the early 1990's, using procedural processing and unification [OCW+00].

By mid-1990's newer frame-based approaches allowed the development of synergistic multimodal systems, i.e., systems that allow both parallel use of input modalities and combined semantic processing [LNP+09].

Newer approaches were published during the 2000's, based on Finite State Automatons, representing context-free-grammars, such as Johnston's and Bangalore's multimodal system [JB05], and Latoschik's extension [LNP+09], which added temporal representation to Johnston's model, thus allowing the processing of simultaneous events generated by the user.

Current approaches are usually based on hybrid approaches, called symbolic/statistical fusion. These approaches use traditional symbolic unification and frame-based approaches, while adding some probabilistic methods such as Bayesian Networks and Hidden Markov Models (HMM) [LNP+09], thus achieving robust and reliable results [DIL09].

2.3.5.3 Advantages

Studies, such as [Ovi97, Ovi00], have shown that multimodal solutions are typically superior to traditional GUI based solutions or unimodal based interfaces, especially in navigational tasks.

Other advantages of Multimodal User Interfaces (MMUIs) are the ability for a user to choose the modality better suited to the task at hand, thus improving stability and the robustness of recognition based systems, in situations where a certain modality might have a high error rate, such as for example in a noisy environment. The possibility to alternate between individual input modalities is also another advantage of these systems, making it possible to avoid injuries caused by overuse of a single modality during long periods of computer use [Ovi01, OCW+00].

One of the most pervasive applications of MMUIs, and considered by some as the main advantage, is in the accessibility and inclusion area where, some studies [DDFG09, dSELJ05] have shown that multimodal interfaces improve the usage experience by disabled, elderly or not so technologically-savvy users, providing the user with a way to choose among the available modalities, according to their specific constraints, thus including users of "different ages, skill levels, native language status, cognitive styles, sensory impairments, and other temporary or permanent handicaps or illnesses" [Ovi01, OCW+00].

2.3.5.4 Issues and Guidelines

Certain issues must be taken into account while developing a multimodal interface based application.

On a more generic standpoint, design issues such as input and output selection, avoiding supplying contradictory or redundant data to the user, user and environment adaptability, consistency and error handling should be thought out carefully, especially when dealing with disabled users [JS07, RLL+04].

These generic issues can be caused by several technical issues, ranging from input recognition errors, system delays, fusion engine issues, or even a combination of these factors [DIL09].

Also, a well-designed multimodal system should be able to deal with imperfect or incomplete data, having the ability to infer conclusions from this data with some certainty. This effect, called multimodal disambiguation, can be done through probabilistic methods such as HMM's, Bayesian networks, or Dynamic Bayesian networks, which are capable of dealing with noisy information, temporal information as well as missing data, using probabilistic inference. More direct and simpler ways of dealing with ambiguity exist, ranging from asking the user, through another modality, what option better suits his previous input, always choosing the first available option or giving preference to one particular modality over another such as speech over gestures, or vice-versa. [JS07, Ovi01, LNP+09].

2.3.5.5 Known Applications

With current technological advances, and the pervasiveness of cheaper ICTs, research in the area of multimodal applications has increased in the past few years, with main-stream support already available in some devices. Research applications range from, tabletops with multi-touch and voice interface support, allowing the development of a collaborative gaming environment [TGS+08], to multimodal media center interfaces [THH+09] and AAL applications geared towards older and disabled users [Cho10, dSELJ05].

More main-stream applications and devices, with support for multimodal interaction, include several iPhone accessibility oriented applications, which support regular interaction through a touch screen and voice recognition [Mac10] and some Android applications such as Google Maps and Google Earth [Goo10].

2.4 HCI Methods

Just as Software Engineering methodologies have evolved over time towards more user-centered approaches, so have HCI methodologies, with current accepted design practices focusing on User-Centered Design.

Regarding design geared towards mobility impaired users, which are the focus of this thesis, more specifically mobility impaired individuals, beyond accessibility focused design approaches, new design philosophies such as Universal Design and Design for all, the latter supported by the E.U. [Com10a], have emerged with the intent of promoting development of products that are can be used by anyone, no matter if they're handicapped or not [Mar03].

2.4.1 User-Centered Design

User-Centered Design (UCD) is an iterative design method where focus is given to what end-users, or more specifically, stakeholders, need, want, as well as their limitations. Users therefore have to be involved as much as possible in all stages of the development process as active members of the development team, so the team can better understand the users' characteristics and capabilities, what they're trying to achieve, as well as how they currently achieve and what improvements can be made to ensure that users can achieve their goals more effectively. Issues such as a person's physical characteristics may affect the application's design, which, considering this work's participants, is a major aspect that will influence the final application's design [SRP02].

Although some alternative models have been proposed as to the number of stages in the iterative development cycle, such as a five stage model encompassing an initial, human values focused stage, called "understanding the individual" [Res08], more commonly a four stage model is used and accepted in the literature [SRP02] such as the one shown in Figure 2.5.

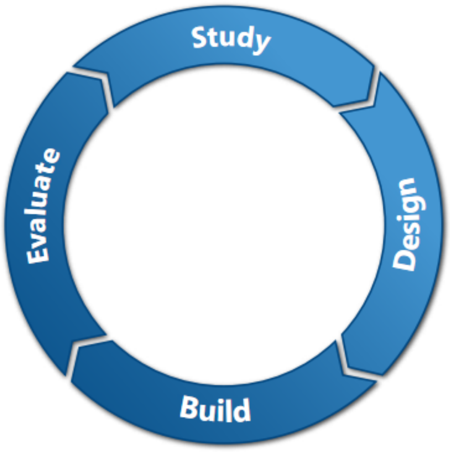


Figure 2.5: A Four Stage iterative design/research model (Source [Res08])

In the *Study* phase, the core activity is the elaboration of functional and non-functional requirements through user-centered data gathering. Some techniques will be described in the following section.

The *Design* stage is essentially a creative phase involving the development of conceptual and physical models of the system, respectively, what the product should do, how it should behave and look like, and, product details such as colors, sounds, text font size, icon and user controls design. Certain best-practice principles, such as Jakob Nielsen's ten usability heuristics [Nie05], should be carefully used in both this stage and the next stage, so as to ensure that the system's usability can be maximized as much as possible.

The *Build* phase involves interactive prototype development which should be usable by the stakeholders. Different techniques can be used here, ranging from paper prototypes, which are inexpensive and easy to build, while being very effecting for identifying problems that may exist at earlier stages of development, or low-resolution and high-resolution prototypes, which can have either mock-up response or actual real-world behaviour.

The fourth and final stage in an iteration cycle, called *Evaluation*, consists of a process where the stakeholders will determine the usability and acceptability of what was built in the previous stages. Issues that should be evaluated in this stage range from number of errors a user founds while using the application to how appealing it is and how it matches the requirements and user expectations [SRP02].

The following two sections describe respectively some data gathering techniques and evaluation techniques, with the latter focusing on multimodal interfaces.

2.4.2 Data Gathering

Data gathering methods are used to either collect relevant data to produce a reliable and stable set of user and technical requirements or, in situations where some initial requirements already exist, to stabilize these [SRP02].

Several methods exist towards this goal, such as questionnaires, interviews, focus groups and observation.

2.4.2.1 Questionnaires

Questionnaires are in essence a series of questions, and can be structured, thus having a pre-specified set of possible answers, unstructured, where the participant can answer the questions in their own words, or semi-structured, having a mix of open and closed questions.

This method is appropriate when one needs a large group of people, in several geographic locations, to answer specific questions. However, unexpected responses and low response rate can be issues that compromise the success of this data gathering method [SRP02].

2.4.2.2 Interviews

Interviews apply similar question and answer methods, while allowing face-to-face contact with the participants. This method, when applied a scenario familiar to the interviewee, allows smoother and more casual information gathering, making it possible for the interviewee to easily recall relevant data.

Some issues, however, also exist with this method, mainly regarding the amount of time needed to conduct the interviews, as well as the possibility for the participant to become intimidated if the interview is conducted in an unfamiliar location [SRP02].

2.4.2.3 Focus Groups

Focus groups are very similar to brain-storming sessions, in which a group of stakeholders are brought together to discuss requirements. Although these sessions allow the collection of multiple viewpoints, there is a possibility of favouritism towards one or more members, mainly when there are hierarchies involved [SRP02].

2.4.2.4 Observation

Naturalistic Observation, or simply observation, allows better data gathering in situations where the participant cannot easily explain certain issues or subjective aspects, such as difficulties using an interface. In this technique, the analyst spends some time with the participants in their natural environment, observing their behaviour, whilst making notes about the setting or clarifying some aspects directly with the participant as they happen. This method allows a better understanding of the context of the participant's activity. It is, however, very time consuming, producing large amounts of data, which can be difficult to analyse.

Note taking, in this method, can be achieved through several means, ranging from a simple notepad and photos, audio recording and photos or video.

These methods however each have their strong and weak points, which can vary from limited writing speed by the observer, to the participant feeling uncomfortable while being recorded [SRP02].

2.4.2.5 Summary

Considering the study's participants, methods such as interviews and observations will be very useful in gathering difficulties that these participants may have with current social media service access applications.

2.4.3 Evaluation

Evaluation is one of the most important stages in the software development cycle. The effects of not doing a good evaluation of the product being developed or no evaluation at all, can be the difference between developing a successful product that satisfies the requirements of the stakeholders, or something that's completely useless to them, similar to what happens when software isn't properly specified (see Figure 2.6).

Several techniques exist geared towards requirements evaluation, depending on the project's context and audience. Two of these methodologies have been previously used in applications with voice and multimodal interfaces, respectively called SERVQUAL and SUXES, the latter of which can be seen in a graphical form in Figure 2.7.

Both methods are very similar, in that they subjectively evaluate users' expectations towards the usage of a particular system before they use the system, evaluate the user experience after system usage, and base the acceptance level for a prototype, according to a tolerance zone defined by the results of the first questionnaire [TLH+09, HST04].

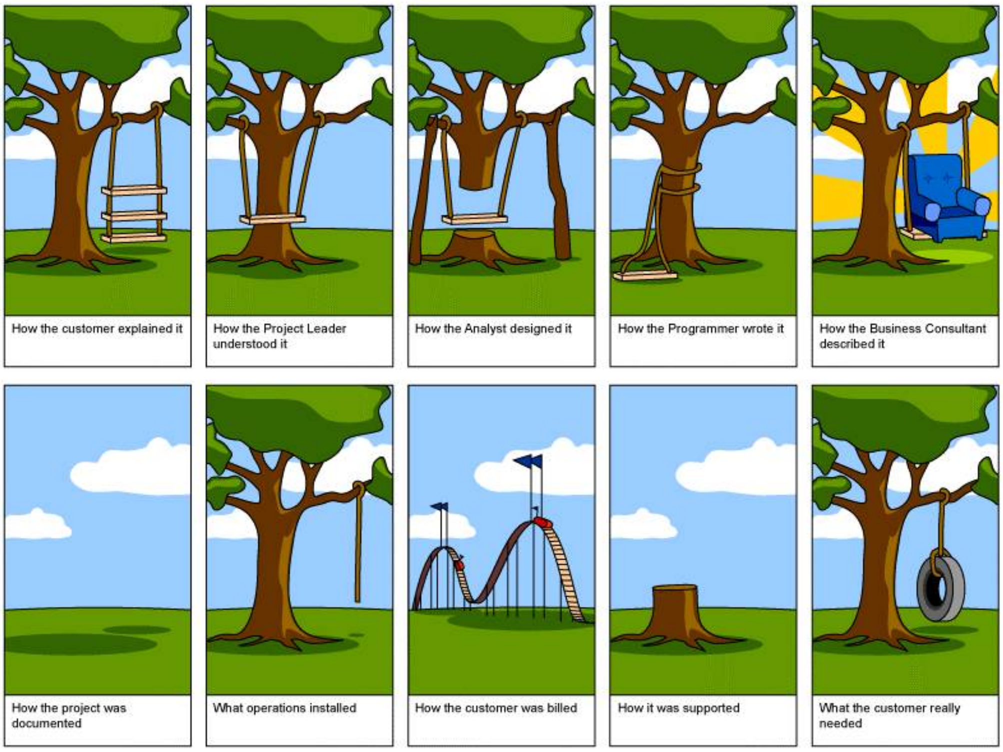


Figure 2.6: Tree Swing Development (Source [Gor])

Both these studies have shown, through their application in concrete case studies, that they're suitable for usage in iterative development and prototyping, allowing the evaluator to obtain concrete information regarding strong and weak features of the project [TLH+09].

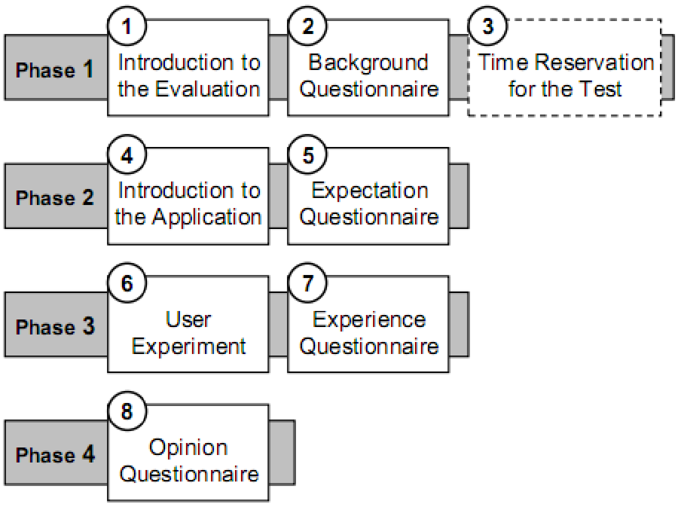


Figure 2.7: SUXES evaluation stages (Source [TLH+09])

2.5 Summary

The evolution of technology over the past half a decade has been tremendously quick, with on-line services dominating current and, possibly, future computing environments. Social Media Services have, thus, surfaced as an on-line means of social interaction, having reached critical mass in the past few years, through mainstream adoption. This has, however, raised concerns regarding usage of these services by individuals requiring specially tailored devices, such as mobility impaired users.

Although some effort has been made to better include these citizens into the digital age, with several initiatives being launched by the E.U. since the year 2000, as history has shown throughout the past thirty years, technology that focuses on allowing better interaction with computerized systems by disabled users has always fallen somewhat behind, considered sometimes as an afterthought, or a secondary aspect, when compared with the possibility of evolving systems and services towards ever more abstract and complex levels.

Even through several types of human-computer interfaces have been developed, geared towards enhancing user interaction with computerized systems, all of them, regardless of being developed with disabled users in mind, or not, have advantages and disadvantages, thus leading to some exclusion or adoption difficulties due to these disadvantages.

The adoption of a multimodal user interface, developed with user-centered design methodologies, focusing on the users' needs, requirements and limitations, may therefore allow the development of better applications geared towards the enhancement of disabled users' experience with computerized systems, by empowering these users to select input and output modalities that better suit their needs and limitations, but can also indulge non-handicapped users' experience, by allowing them to choose adequate modalities, based on their profile, spatial or even environmental limitations. This hypothesis will be tested in the remainder of this work.

Furthermore, these advantages have been shown to accurate in real-world situations, through several studies, which suggests that such an approach can produce meaningful results towards the improvement of the quality of life of mobility impaired individuals while, at the same time, being an inexpensive and powerful solution, not only to their problems, but also to problems experienced in other contexts, as already suggested in this section.

Chapter 3

Requirements Analysis

3.1 Introduction

Social Media Services (SMS's) have evolved from their initial concept, supporting the maintenance of user profiles and connection lists, as well as viewing and traversing these lists, as defined by Boyd in [BE07], to more complex systems powered not only by humans and their interactions, but also by content with specific meaning associated to it. With the constant evolution of SMS's, as with most technological evolutions over time, accessibility has often been considered a secondary concern, excluding impaired users from these achievements. This chapter does an initial analysis of the problem at hand, followed by the results of two requirements' analysis sessions.

3.2 The Problem

Just as in real life situations, mobility impaired individuals face several obstacles in their daily lives, while interacting with the digital world which must be overcome. On the one hand, most web-site developers don't think about this and other kinds of restrictive access situations, and even though Web Accessibility guidelines exist [Wor10b], most don't even bother to follow them. Issues such as small text and links, nested menus, complex layouts, dynamic pages, CAPTCHA's, all lead to the creation of unfriendly digital environments for impaired individuals [Col09, Dol10, Wat09, Whi07]. Applications for accessing social media services in both mobile and desktop environments also share some of these issues. Small and hard to find graphical elements, overly complex interfaces, dynamic elements in the user interface that make it very difficult to use adaptive technologies already built into operating systems, or 3rd party ones, and usage of service specific terms, are some of the issues pointed out by mobility impaired users that reduce their user experience with SMS applications [bTC09, jTC09]. As already mentioned in the previous chapter, these services can be used to reduce the effect that real world barriers have on the social interaction and integration of these individuals. User groups on Facebook and MySpace focused in disabilities and rehabilitation already exist, which can be used by these individuals to enhance their social interaction with other people in their situation or in similar situations [Han09]. Despite these issues, certain services such as Facebook or Twitter have taken some steps to increase the easiness of use by impaired users, supplying a simpler HTML based interface compatible with screen readers, as well as audio CAPTCHA's [Fac10b, MC09]. Facebook's iPhone application has also been improved with several accessibility fixes, as well as support for VoiceOver, Apple's screen reader technology, available for Mac OS X and the iPhone OS [cN09]. The availability of open APIs to some SMS's have made it possible for third party developers to build applications geared towards impaired individuals, such as *Accessible Twitter*, *Easy YouTube* or *Nomensa's Accessible Media Player*, therefore allowing easier access to these services [Lem10, Wat09]. These third party solutions are, however, too focused on specific services and audiences. The focus of this work is therefore to explore a different approach that is more generic, supporting different kinds of services and users.

3.3 Requirements Analysis

3.3.1 Introduction

Two user study sessions were conducted in January and March, respectively over the Internet and in person. A group of eleven mobility impaired members from Associação Salvador [aS10] volunteered to take part in this study. The first session consisted of a collective interview, where a group of five mobility impaired individuals, Participants 1 through 5 as specified in table A.1, replied to the questionnaire available in Appendix A, section A.2. This session allowed the capture of ICT usage patterns by mobility impaired users, as well as their main difficulties while using ICTs and which modifications would benefit their interaction with technologies such as computers, cellphones, smartphones and social media services. Considering this session's objective was to gather initial information to be further explored in future studies, it was considered sufficient to use a participant panel of just 5 individuals with different handicap degrees and ICT use proficiency.

The second session consisted of a task-based study followed by individual interviews with each participant, lasting each about two hours. The whole study lasted four days and included ten participants. Considering the objective of this study was to gather as much valuable information as possible towards the elaboration of the final prototype, it was necessary to expand the participant sample size. In the beginning of each session, the session's goals were explained to each participant, and they were told to fill in a small questionnaire and a consent form. During each session, audio and video was recorded for further analysis. The questionnaire consisted of a subset of questions from the first session, filled by those individuals who didn't take part in the previous round, so as to determine their ICT usage pattern, thus obtaining more statistically valuable data. Some additional questions were asked to all participants, regarding their interest in abstract web services, as described in Appendix A, section A.3. With this data in hand it's possible to better determine where to focus social media service development.

Participants were asked to choose one of several available social media services, preferably one with which they were familiar to reduce biasing the results due to user inexperience with a particular service, to execute a set of tasks specified for the chosen service. In the end of the task, participants were asked which difficulties they felt during the task, what they would improve in the service they just used and how alternative modalities such as touch, gestures and speech interaction could enhance their user experience with the service. Finally, participants were asked to test computer interaction through a digital stylus and speech recognition on a tablet PC, as well as through touch and accelerometer interaction (3D Gesture) on a smartphone. At the end of these interactions, participants were asked to reply a series of questions regarding their easiness of use of each modality, as specified in Appendix A, section A.3. In the following sections, a more in-depth analysis is made on the data gathered over these two sessions, taking into account vital information that will be taken into account for the specification and implementation of the prototype.

3.3.2 Study Participants

Due to the nature of the development process and targeted user group, mobility impaired individuals, this work was conducted in collaboration with Associação Salvador, who kindly provided the contacts of some of their members who volunteered to take part in this research. These participants were of different ages, and had different impairments and computer usage experience. A control participant was also used during the second round of interviews as a means of comparison. Participants were, whenever justifiable, divided into 5 groups: the control user, quadriplegic, paraplegic, all participants, proficient paraplegic and proficient quadriplegic. The all participants group encompasses all paraplegic and quadriplegic participants that took part in the specified task. Disable participants were placed into their respective proficient user group whenever it was noticeable that they had a high level of experience using the proposed interaction modalities, as well as the selected UIs and services. The following table describes the group of participants in more detail.

Name	Sex	Age	Professional Area	Disability
Control	Male	22	Student	None
Participant 1	Female	25	Life Sciences Technician	Quadriplegic
Participant 2	Male	43	Computer Technician	Quadriplegic
Participant 3	Male	47	Book Keeper	Paraplegic
Participant 4	Female	26	Unemployed (Social Psychologist)	Paraplegic
Participant 5	Male	28	General Manager	Quadriplegic
Participant 6	Male	37	Unemployed	Quadriplegic
Participant 7	Male	36	Computer Technician	Paraplegic
Participant 8	Female	54	Technical Assistant	Paraplegic
Participant 9	Male	41	Computer Engineer	Quadriplegic
Participant 10	Male	19	Student	Paraplegic
Participant 11	Male	40	Enologist	Quadriplegic

Table 3.1: Study Participants

3.3.3 Prior Experience Analysis

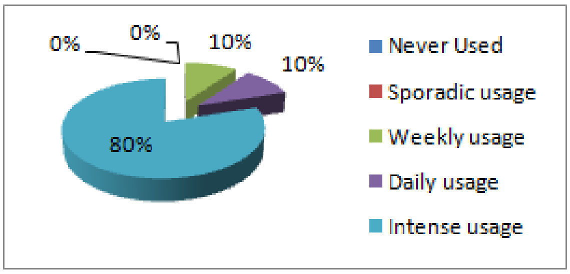
Regardless of their limitations, the conducted inquiries revealed that all participants are avid computer users, as can be seen in Figure 3.1(a), with the majority (80% of participants) using these devices for more than five hours a day, which is considered in this study as "Intense Usage". This trend can also be seen when a division by physical limitation is made, however, as can be seen in Figures 3.1(b) and 3.1(c), quadriplegic individuals have a slight tendency to use computers more frequently that paraplegic individuals.

As noted in Appendix A, section A.2, and as observed during the study sessions, the majority of individuals interviewed use computers daily as a tool for work-related tasks. Of these, approximately 40% dedicate at most 10% of their time for personal tasks such as watching videos and movies or listening to music, as can be seen in Figure 3.2.

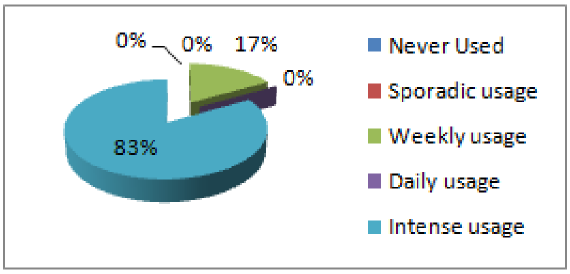
Regarding computer savviness, the interviewees follow an almost normal curve distribution, with a slight tendency to medium-high savviness, as can be seen in Figures 3.3(a) and 3.3(b). This data, along with usage patterns shown in Figure 3.1, reveal that these users are very dependent on computers to perform their daily work tasks. They stated, however, that there is still room for interaction improvement beyond the plain keyboard and mouse they're used to.

Cellphones are used by the interviewees on a daily basis, with the majority using them at most five hours a day, while 30% use these devices for more than five hours days, as seen in Figure 3.4(a). This trend can also be seen when results are shown separately for each type of physical limitation (Figures 3.4(b) and 3.4(c)).

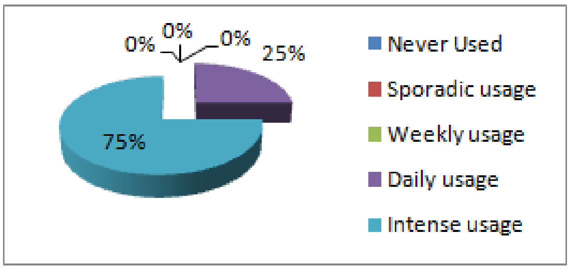
The study also revealed that the majority of individuals interviewed also use cellphones as a tool in their daily work related tasks, with a slight emphasis on work related



(a) Global Chart



(b) Quadriplegic individuals



(c) Paraplegic individuals

Figure 3.1: Computer usage by participants

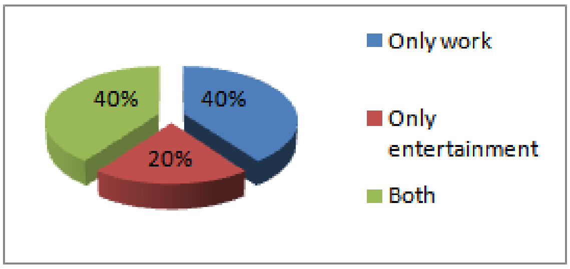
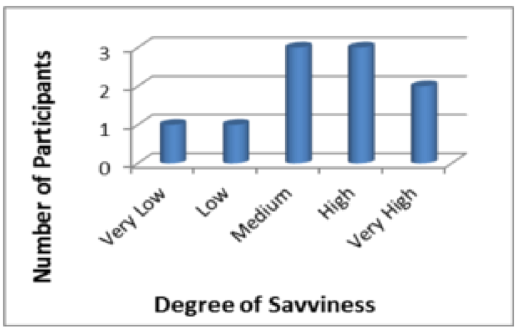
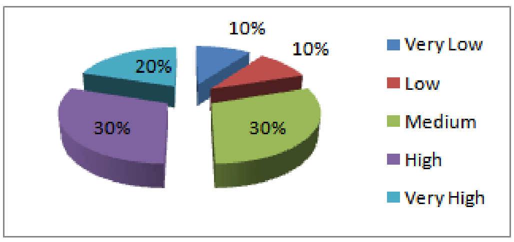


Figure 3.2: Computer tasks executed by the interviewees



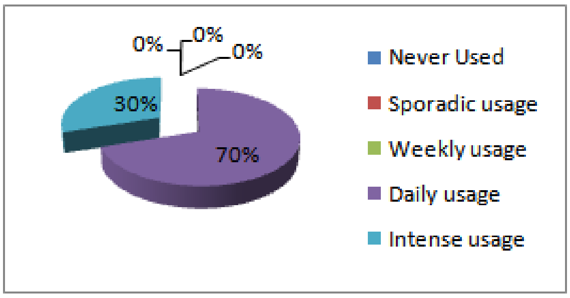
(a) by bar chart distribution



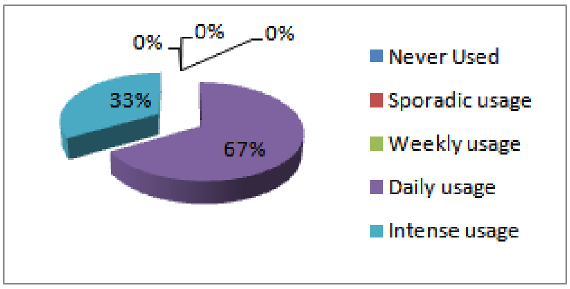
(b) by Percentage

Figure 3.3: Computer savviness

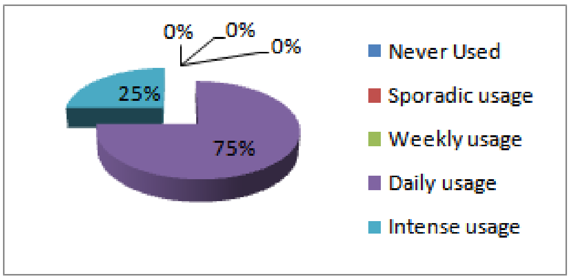
tasks, rather than personal tasks, although slightly less frequently that with computers, as



(a) Global Chart



(b) Quadriplegic individuals



(c) Paraplegic individuals

Figure 3.4: Cellphone usage by participants

can be seen in the previous charts. Of these, approximately 20% dedicate at most 10% of their time for personal tasks, as can be seen in Figure 3.5.

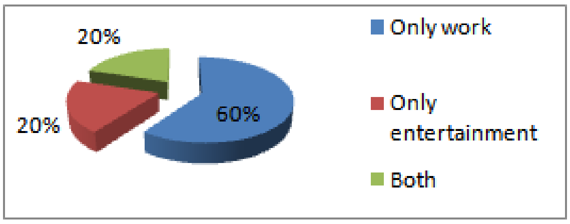
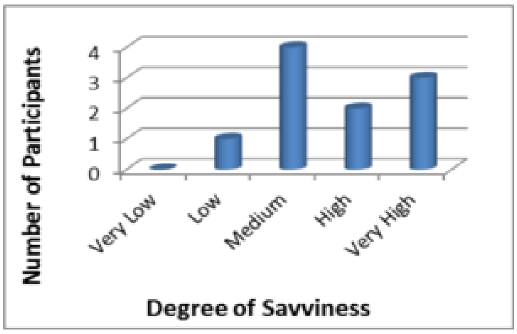


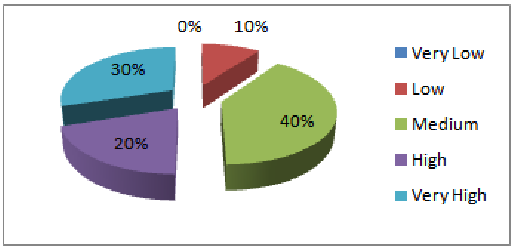
Figure 3.5: Cellphone tasks executed by the interviewees

Cellphone usage savviness has a tendency towards the interval between medium and very high, as seen in Figures 3.6(a) and 3.6(b), clearly showing that, overall, the interviewees feel more comfortable using a cellphone than a computer. They also stated that issues such as small cellphone keys and small icons on touch screen cellphones abruptly reduce their user experience.

Of the ten participants who took part in these sessions, only two have actually used a smartphone as part of their daily work tasks, Participants 7 and 11. When asked why they didn't use smartphones, the remaining individuals answered that they either felt that their current cellphones filled their mobile communication needs, or that they felt their physical limitations made it very difficult, if not impossible to interact with a small touch



(a) by bar chart distribution



(b) by Percentage

Figure 3.6: Cellphone savviness

screen.

3.3.4 Social Media Services Analysis

3.3.4.1 Introductory questionnaire

The study participants were asked, at the beginning of each session, to answer a small questionnaire regarding social media services (SMSs) usage and preferences. The questionnaire and respective results are as follow:

Scale A:

1 - Never used
2 - Sporadic usage (less than once a week)
3 - Weekly usage (at least once a week)
4 - Daily usage (less than five hours a day)
5 - Intense usage (more than five hours a day)

Who do you believe ICTs help you keep in touch with?

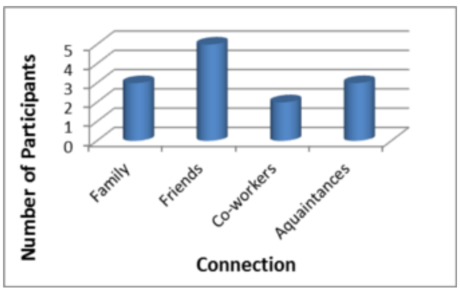
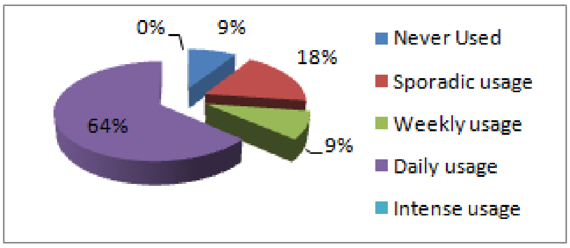


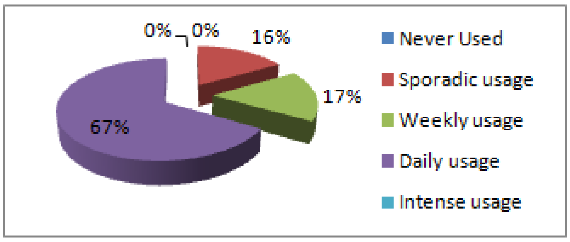
Figure 3.7: Contact chart

Although this initial question was only asked to participants who participated in the first session, due to time constraints on the second session imposed by the participants' availability, a tendency towards contact with friends is noticeable in Figure 3.7.

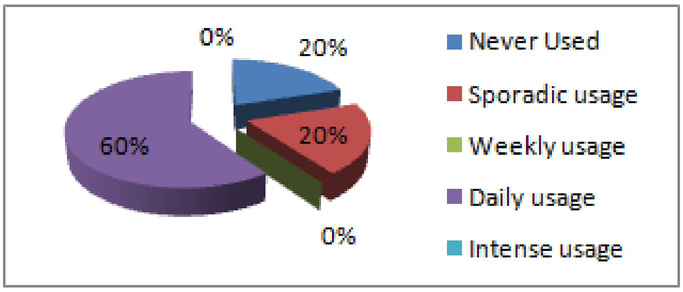
On average, how would you describe your social media services' usage habits (according to scale A)?



(a) global rates



(b) only quadriplegic individuals



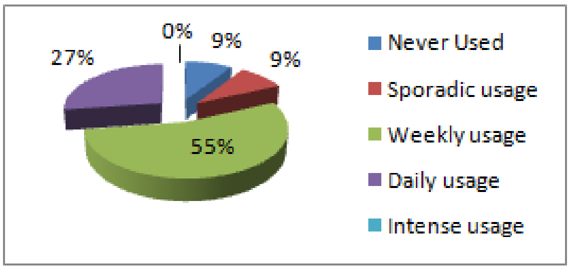
(c) only paraplegic individuals

Figure 3.8: Usage of social media sites by the study participants

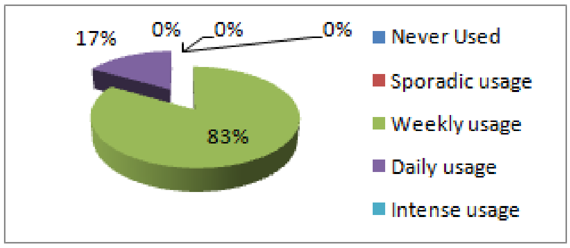
As can be seen in Figures 3.8, the majority of participants currently use social media services on a daily basis. By comparing charts 3.8(b) and 3.8(c) it's possible to see that quadriplegic individuals are more avid users of social media services.

On average, how would you describe your content sharing services' usage habits (according to scale A)?

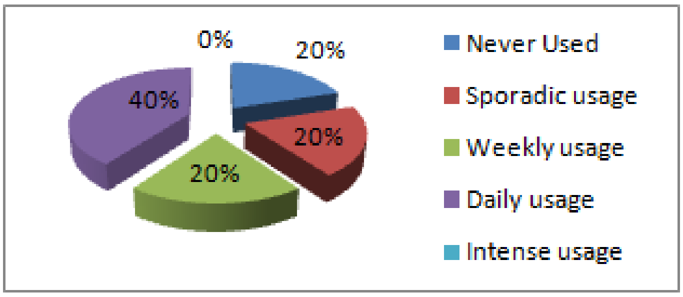
As it would be expected from the results shown in Figure 3.2, the users follow a more work-centric approach to computer usage, which can clearly be observed in Figure 3.9, as content sharing site usage trends towards weekly use in the majority of cases. Nonetheless, paraplegic individuals who took part in this study reveal a more evenly distributed usage pattern, with some concentration on the weekly through daily usage levels.



(a) global rates



(b) only quadriplegic individuals



(c) only paraplegic individuals

Figure 3.9: Usage of content sharing sites by the target audience

Which social media sites have you heard of?

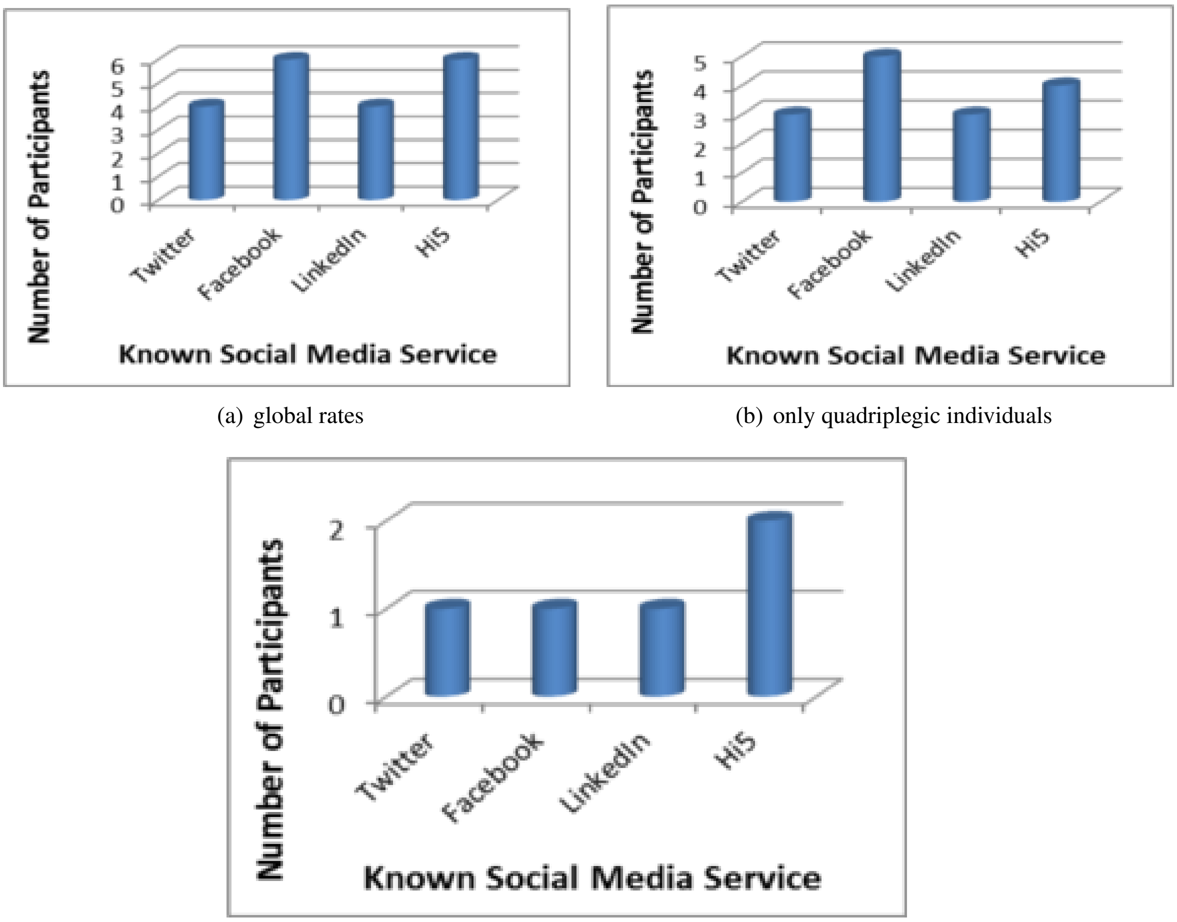
Due to the mass presence of Facebook in mediums such as TV or radio, and large communities of Portuguese users in Hi5, the results presented in Figure 3.10 were as expected. One notable exception is Twitter, whose presence is below what was expected, considering that its presence in mass media is as high, if not more, than Facebook.

Which social media sites have you used?

Also, as expected, Facebook usage prevails over the alternatives presented, as can be seen in Figure 3.11. Usage of other SMSs such as Twitter or Hi5 drop significantly from the results obtained in the previous question. When confronted about this, users answered that Twitter and Hi5 are either too confusing to use or that other users of these SMSs are too *chatty*, often having meaningless conversations. Participants found however, LinkedIn very useful to maintain contacts in their professional areas.

Which content sharing sites have you heard of?

Again, due to mass media presence, YouTube is considered, as expected, the most known content sharing / social media service by the interviewees. Flickr is also known by some users, however, not as much as YouTube. When told about Last.fm's functionalities,



(a) global rates

(b) only quadriplegic individuals

(c) only paraplegic individuals

Figure 3.10: Known social media services

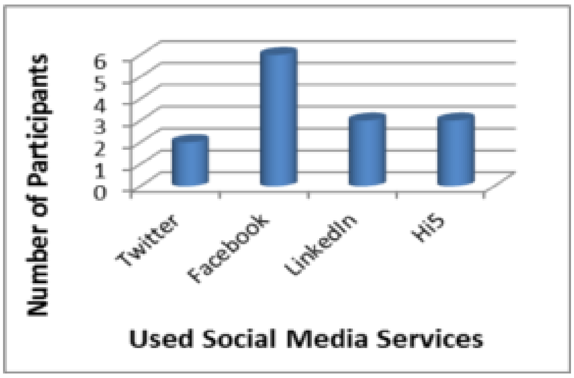
however, most users expressed interest in using the service in the future. These results can be seen in Figure 3.12.

Which content sharing sites have you used?

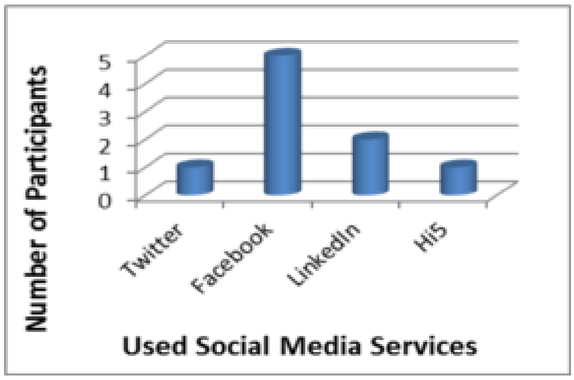
In the case of YouTube, all users who know the site are also users of it, as can be seen in Figure 3.13. The majority of users of both YouTube and Flickr, however, noted that their usage is done in anonymous mode to visualize videos and photos, with only a small minority using these services to actually post content.

Of the following sentences, please tick those that you believe are true:

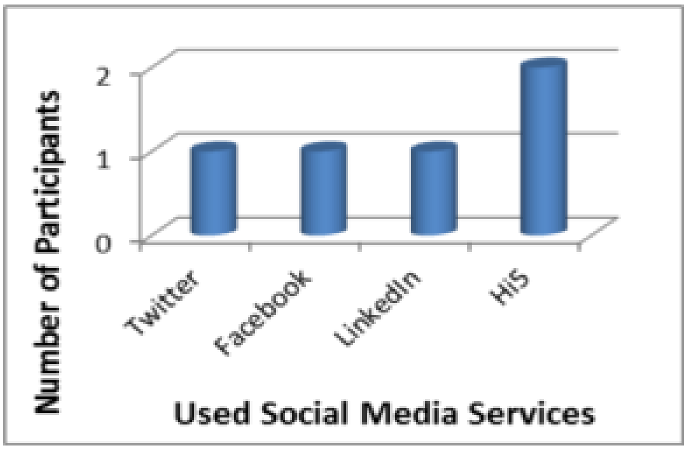
a. - I'm interested in following my friend's/relative's activities through the internet;
b. - I'm interested in receiving news updates from the internet;
c. - I'm interested in publishing personal activity updates to the internet;



(a) global rates



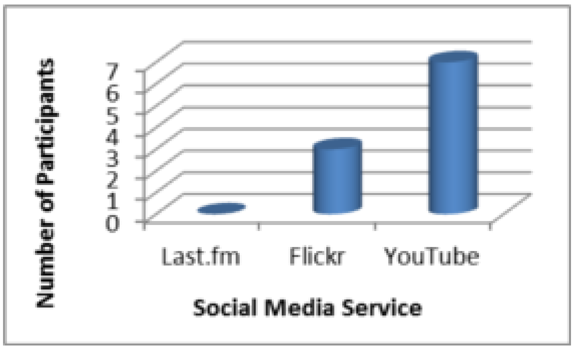
(b) only quadriplegic individuals



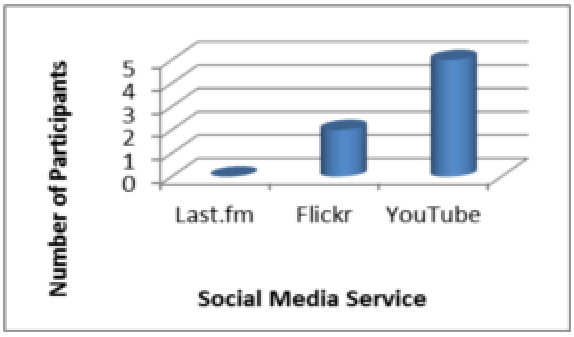
(c) only paraplegic individuals

Figure 3.11: Social media sites used by the study participants

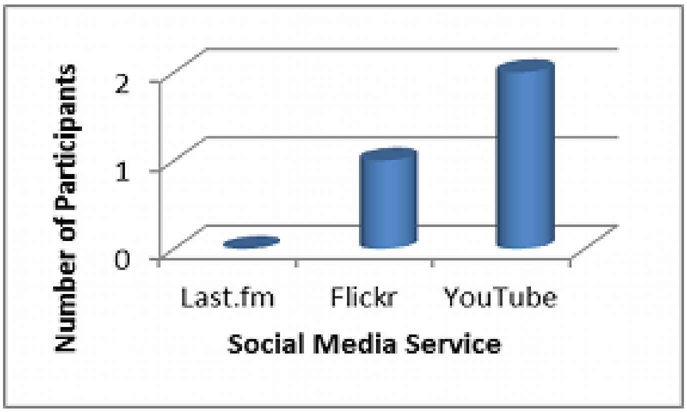
d. - I'm interested in sharing photos with friends/relatives through the internet;
e. - I'm interested in viewing photos on the internet;
f. - I'm interested in long term on-line photo storage;
g. - I'm interested in sharing videos with friends/relatives through the internet;
h. - I'm interested in watching videos on the internet;
i. - I'm interested in long term on-line video storage;
j. - I'm interested being notified of events close to my current location, through the internet;
k. - I'm interested in confirming my presence in events, through the internet;
l. - I'm interested in communicating with groups of people with whom I share some interests, over the internet;
m. - I'm interested in listening to music over the internet;
n. - I'm interested in communicating with people with whom I share musical interests, over the internet;
o. - I'm interested in establishing professional contacts over the internet;



(a) global rates



(b) only quadriplegic individuals



(c) only paraplegic individuals

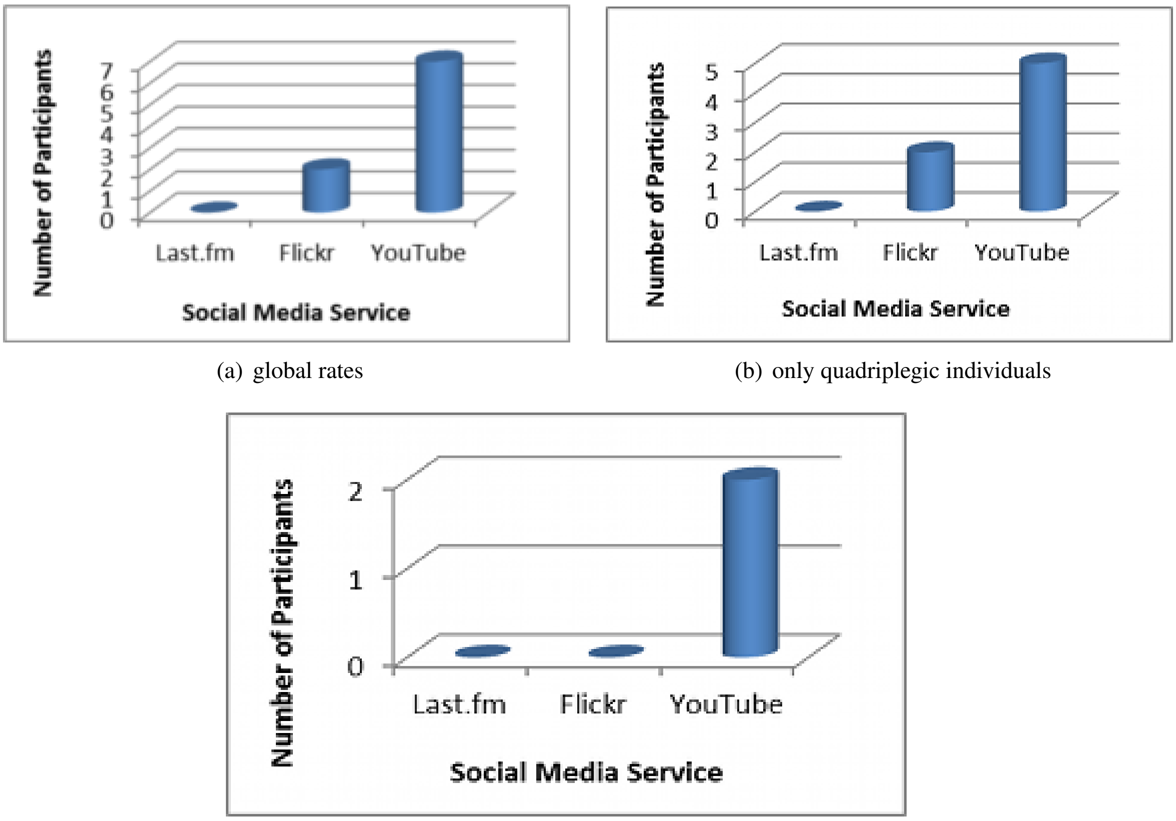
Figure 3.12: Known content sharing services

This question was posed with the intent to indirectly obtain user preferences with regards to SMSs. With the results presented in Figure 3.14, it's possible to reach the following conclusions:

1. The study participants, in general, are interested in being up-to-date with the latest news and events, following the activities of their friends and relatives, viewing photos, videos, listening to music and communicating with new people with whom they share some kind of interest.
2. The previously mentioned activities are supported in Twitter, Facebook, Flickr, YouTube and Last.fm, which makes these services of interest for the development stage, namely the prototype application.
3. These interests can be seen in both quadriplegic and paraplegic interviewee groups.

3.3.4.2 Current UI usability evaluation

As mentioned in section 3.3.1, the second study session consisted in the execution of a set of tasks directly related with social media services, namely, interaction with some of the currently available social media services' user interfaces, to assess how easy or difficult it



(a) global rates

(b) only quadriplegic individuals

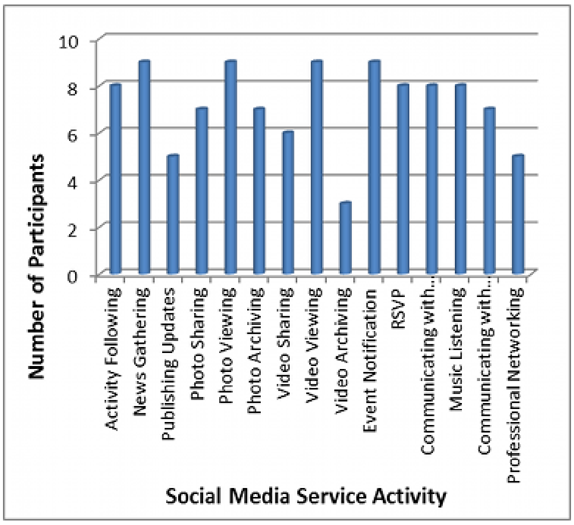
(c) only paraplegic individuals

Figure 3.13: Content sharing sites used by the study participants

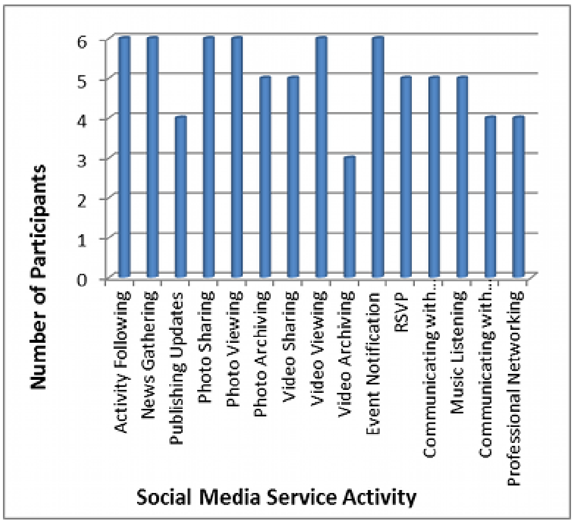
is for mobility impaired individuals to use these services, as well as how to enhance their user experience. In some situations, task execution took longer than initially estimated, in which case, the sub-task under execution was skipped, should there still be other sub-tasks and time remaining, otherwise, the whole task was aborted. These time constraints were defined due to the temporal availability some participants expressed. Whenever the participant felt difficulties executing a particular sub-task and asked for help, it would be supplied, and a note would be taken about where and how the participant reached that situation. In the end of the task, participants were asked the set of questions specified below:

1. Did you enjoy using this service?
2. Did you find this service easy to use? If not, what would you change about it?
3. Do you believe that alternative modalities such as speech or touch would improve your interaction with these services? If so, how would they improve your interaction?

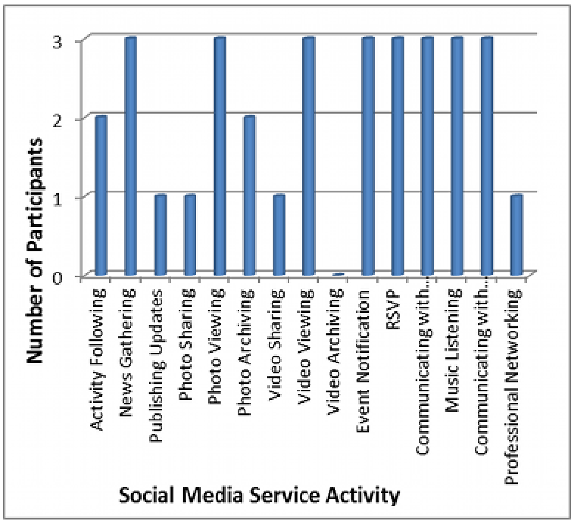
Tasks were performed in quiet, calm, controlled environments, either in meeting rooms or at a location specified by the participant. The same hardware was used in every session,



(a) global rates



(b) only quadriplegic individuals



(c) only paraplegic individuals

Figure 3.14: Social Media Services user interest profiles

as specified below, and before task execution, all service test user accounts previously used in other sessions were reset, to guarantee that no side effects from previous accesses appeared during the task. With the exception of participants 3 and 5, as well as 8 and 9, who participated in joint sessions, all other participants were interviewed individually.

Tablet PC:

- Toshiba Tecra M4
- Intel Pentium M 2.0 Ghz
- 2 GB RAM

- Windows 7 Enterprise 32 bits
- Internet access: Wifi, ethernet, CDMA card (depending on access availability on-location)
- Browser: Internet Explorer 8 or Mozilla Firefox 3.6 (depending on user preference)

Tasks

Participants were asked to use one of seven social media services (SMS), according to their preferences. Most individuals chose a service with which they were already familiarized, however, some preferred to use a different one to try something new that they hadn't yet used. Test user accounts were created and supplied to the participants for each chosen SMS, to create a more controlled user environment. The following table shows which SMSs were proposed to the participants and their respective user interfaces (UIs).

SMS	Web UI	Desktop UI
Twitter	twitter.com, search.twitter.com, twitpic.com	DestroyTwitter
Facebook	facebook.com	N/A
YouTube	youtube.com	N/A
Flickr	flickr.com	N/A
Last.fm	last.fm	Last.fm Scrobbler
LinkedIn	linkedin.com	N/A
Digg	digg.com	N/A

Table 3.2: Social Media Services' User Interfaces

Details about the tasks are provided in Appendix F.1.

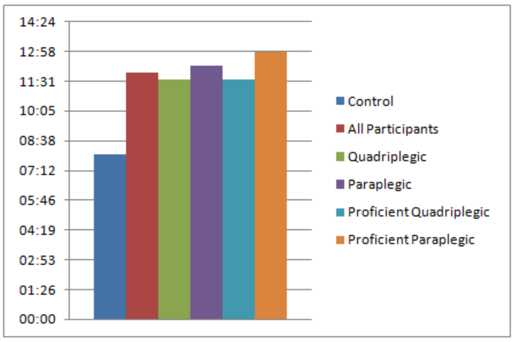
Message-centric Services

Besides determining user interaction difficulties associated with each service, the tasks conducted with message-centric services allowed the overall evaluation of how mobility impaired users type on the keyboard.

Detailed results of these evaluation sessions can be consulted in Appendix F.2.

Considering that the tasks proposed for both Twitter and Facebook are very similar in difficulty and execution time, it's possible to use both these SMSs to find issues in terms of writing difficulties. Although quadriplegic participants took overall less time to finish these tasks, as can be seen in Figure 3.15, something that can be explained from the proficiency with ICTs that these users expressed throughout the evaluation, they had significantly more difficulties using the keyboard, as they used one or at most two fingers to type at any given time, with some using their finger knuckles to type. Participant 2 used a set of pencils as a writing aid during this task, allowing him to reach significantly faster typing speeds than other quadriplegic participants. However he took more than 14 minutes to complete his set of tasks on Twitter. This can, however, be justified by the fact that, as opposed to other quadriplegic participants, he wasn't as proficient with Twitter as others were with Facebook.

Participants 2 and 9 had some issues inserting these special characters, adding that other key combinations such as Ctrl+Alt+Delete also posed a serious challenge to use, requiring them to use aids such as a pencil eraser to simultaneously press two of those keys. Participant 11, however, noted that he uses sticky keys to overcome that problem. Nonetheless, all quadriplegic participants, including those who used media-centric services, when asked, replied that a toolbar with special characters and key combinations would be very useful to them.



(a) Chart Form

	Average	Standard Deviation	Difference
Control	07:58	01:14	03:58
All Participants	11:55	01:32	
Quadriplegic	11:35	02:16	00:42
Paraplegic	12:16	00:38	
Proficient Quadriplegic	11:35	02:16	01:22
Proficient Paraplegic	12:57	-	

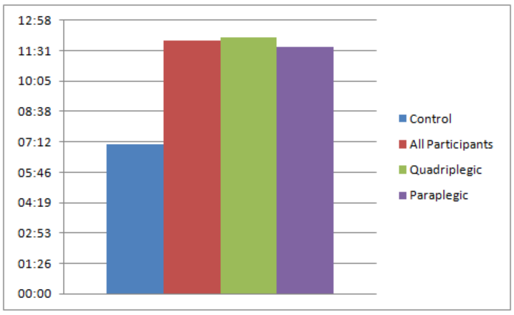
(b) Table Form

Figure 3.15: Twitter and Facebook task average execution times

Twitter Tasks

Participants were asked to try out most of Twitter's base functionalities such as message sending (*Tweeting*), forwarding (*Re-Tweeting*) and replying. They were also asked to try some third party services like *TwitPic* (picture uploading and short url generation) and search facilities. Proficient ICT users such as participants 2 and 9 didn't have major difficulties using these services, although they did express some concerns regarding small links, UI controls and hard to read colors in *TwitPic's* web page and *DestroyTwitter's* UI. Participant 8 hadn't previously used any SMS and as such, had many difficulties finding options in the UIs that were not so visible. Overall participants also had some difficulty associating service specific terms such as *Tweeting* to their actual meaning, a difficulty expressed whenever they weren't directly asked to execute an action by its service specific functionality name.

The control user result presented in Figure 3.16 can be considered a goal time for future evaluations with participants of this study. A clear temporal difference of about 5 minutes is observable between the control and the participants who chose this service, which shows that there is still room for interaction improvement. There is a small difference between the average time it took for a quadriplegic and paraplegic participant to



(a) Chart Form

	Average	Standard Deviation	Difference
Control	07:05	-	04:54
All Participants	11:59	02:04	
Quadriplegic	12:07	02:55	00:26
Paraplegic	11:42	-	

(b) Table Form

Figure 3.16: Twitter task average execution times

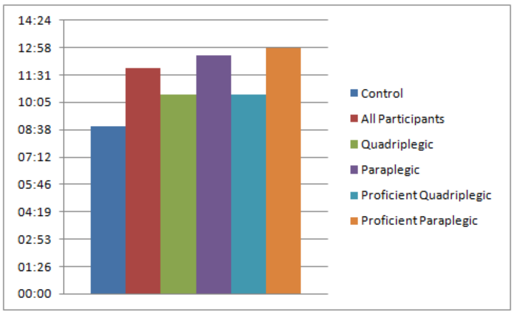
execute this set of tasks, however, the difference of 30 seconds is somewhat insignificant. It's possible, however, to extrapolate through the interaction results in other SMSs that this difference would be larger should a non ICT-proficient quadriplegic participant take part in this evaluation.

The following are some guidelines that should be taken into account to develop a Twitter UI that's simple enough to be used by non-proficient mobility impaired users. These were derived from the previously presented data, as well as from qualitative data available in Appendix F.2:

- It should be simple enough to use, and should not use service specific jargon.
- It should have a readable interface, where all items and options are understandable and visible, having large text and icons that can be seen at some distance from the monitor, as some users must use these interfaces from their wheelchairs at some distance from the monitor.
- The UI should also use a color scheme that makes it readable at some distance from the monitor.
- It should be possible to interact with the UI through different modalities, in accordance to user preferences. Speech interaction should be available wherever possible, as stated by the participants.

Facebook Tasks

While using Facebook, participants were asked to perform some of the more common tasks like posting a message on a user's wall or sending a user a private message to assess writing issues. Participants were also asked to perform tasks like friend management, and media management tasks like photo and video upload and visualization, also with the intent to determine interaction difficulties. Overall participants think that Facebook uses simple concepts, however, features are organized in a complex way, with too much information condensed into a single page, which can make it difficult to retrieve information. Even the more proficient users like participants 7 and 11 had difficulties finding more hidden features like video upload and management. Participants stated that alternative modalities like speech or touch, as well as simpler menu systems and pages would speed up their interaction with Facebook.



(a) Chart Form

	Average	Standard Deviation	Difference
Control	08:50	-	03:02
All Participants	11:52	01:16	
Quadriplegic	10:19	-	02:04
Paraplegic	12:33	00:33	
Proficient Quadriplegic	10:19	-	02:28
Proficient Paraplegic	12:57	-	

(b) Table Form

Figure 3.17: Facebook task average execution times

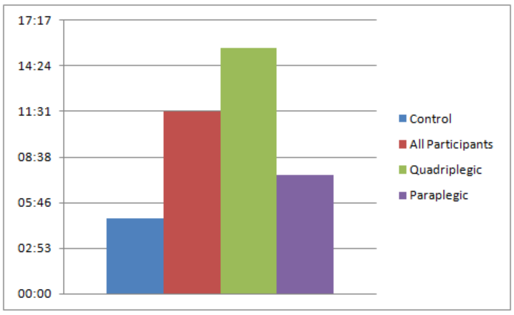
In this case, participant 11 managed to finish his task faster than all other participants, as can be seen in Figure 3.17 due to his usage of sticky keys and extensive knowledge of the layout of Facebook. He did, however, have some issues with typing speed when compared to paraplegic participants. Although the difference between participants 3 and 7 is of about 30 seconds, it should be taken into account that participant 3's task execution was aborted due to time constraints and, considering the participant still had to complete some tasks and was having some difficulty location elements on Facebook, it is expected that his evaluation run would last more than participant 7's run.

Tthe following are some guidelines that should be taken into account to develop a Facebook UI that's simple enough to be used by non-proficient mobility impaired users. These were derived from the previously presented data, as well as from qualitative data available in Appendix F.2:

- Functionalities should have less information condensed into a single location.
- All items and options should be understandable and visible, having large text and icons that can be seen at some distance from the monitor.
- The current UI color scheme seems to be readable and appealing, so it should be taken into consideration as a whole application scheme.
- It should be possible to interact with the UI through different modalities, in accordance to user preferences. Speech interaction should be available wherever possible, as stated by the participants.

YouTube

As with other services previously analysed, participants were asked to interact with basic service features such as user profiles, video uploading and visualization, as well as service specific features like channel subscriptions and playlists. User experience by both participants who chose this service was very divergent. Participant 10 had already previously done most of the proposed tasks, and as such had little difficulty interacting with YouTube. He did however find that the way playlists and user profiles are manipulated to be somewhat confusing due to an excessive amount of links and submenus available in these pages. Participant 6 had also previously used YouTube, however, he had only used it in anonymous mode, and as such wasn't very familiar with user profiles and user specific options. This participant noted that his difficulties were not only due to him never having seen the user specific features, but also due to the presence of small, hard to read links, hidden submenus that were difficult to find out about, and complex menus, especially in the user profile. Participants also stated that alternative modalities may help find information, especially when dealing with complex menu structures and data-intensive UI components.



(a) Chart Form

	Average	Standard Deviation	Difference
Control	04:46	-	06:44
All Participants	11:30	05:39	
Quadriplegic	15:30	-	08:00
Paraplegic	07:30	-	

(b) Table Form

Figure 3.18: YouTube task average execution times

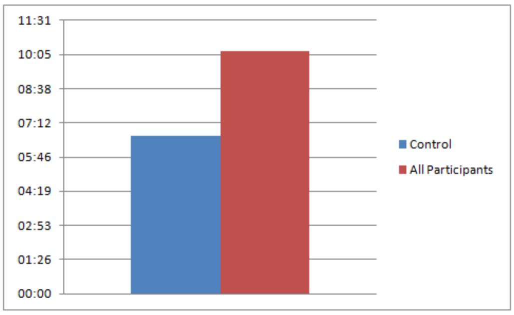
As would be expected, considering the difficulties participant 6 expressed while using the service, the mean difference between both participants' execution times is of 8 minutes. Considering participant 6's session was aborted close to its end due to technical issues, the final time, should it have finished wouldn't vary much from this value. This shows that a different approach for inexperienced quadriplegic users, and even for paraplegic users could produce results close to the control participant's results. These results can be seen in Figure 3.18.

The following are some guidelines that should be taken into account to develop a YouTube UI that's simple enough to be used by non-proficient mobility impaired users. These were derived from the previously presented data, as well as from qualitative data available in Appendix F.2:

- It should have a simple and readable interface, where all items and options are understandable and visible, having large text and icons that can be seen at some distance from the monitor.
- The UI should also use a color scheme that makes it readable at some distance from the monitor.
- It should be possible to interact with the UI through different modalities, in accordance to user preferences. Speech interaction should be available wherever possible, as manifested by the participants.

Last.fm

In this case, only one participant chose to use Last.fm, however, valuable data was still recovered towards the development of media-centric applications Participant 1 had almost no issues interacting with Last.fm's web UI, managing to overcome by herself some technical issues that happened during the session. The participant found the web UI easy to use, but noted however that Last.fm's scrobbler application was visually unappealing and confusing to use, especially due to the lack of legends and tooltips on the control buttons. She also believes that usage of voice control in this service would reduce the learning curve and free the user to perform other tasks with his/her hands.



(a) Chart Form

	Average	Standard Deviation	Difference
Control	06:40	-	03:33
All Participants	10:13	-	

(b) Table Form

Figure 3.19: Last.fm task average execution times

Although the participant didn't experience as many difficulties as previous study participants, and taking into account that the final time shown on the above chart does not include the time it took to solve some technical issues, there is still a difference of three and a half minutes between the control user and the participant. As such, there is still room for interaction improvement, especially when considering that most issues experienced by the participant were caused by difficulties while interacting with the desktop application. These results can be seen in Figure 3.19.

The following are some guidelines that should be taken into account to develop a Last.fm UI that's simple enough to be used by non-proficient mobility impaired users.

These were derived from the previously presented data, as well as from qualitative data available in Appendix F.2:

- It should have a simple and readable interface, where all items and options are understandable and visible, having large text and icons that can be seen at some distance from the monitor.
- The UI should also use a color scheme that makes it readable at some distance from the monitor.
- The Last.fm UI should closely resemble the web UI so as to be more appealing than the current scrobbler UI.
- Tooltips and contextual help should be available on the UI's components.
- It should be possible to interact with the UI through different modalities, in accordance to user preferences. Speech interaction should be available wherever possible, as manifested by the participants.

Discussion

This interaction analysis shows that in most situations, users feel overwhelmed by the amount of functionalities social media services (SMS) offer, making these services confusing to use, especially when it's the user's first attempt at doing a specific task. Although there are some exceptions, especially when participants have had some prior experience with SMSs, overall quadriplegic participants have expressed more difficulties while using traditional interaction modalities such as the keyboard and mouse combination than paraplegic users, which leads them to be somewhat less productive than paraplegic individuals, especially participants with higher levels of quadriplegia such as participant 5. For these cases, speech interaction in dictation and command & control modes is considered as an alternative with potential to increase the participant's productivity in using ICTs. Participants do believe, however, that dictation would be more useful than command & control, especially those who elaborate large texts during their daily activities.

3.3.5 Interaction Modality Analysis

The previous section focused on analysing participant interaction with social media services through regular interaction modalities like the keyboard and mouse. The analysis presented in this section focuses on the use of several interaction modalities, in an attempt to gather more information on quadriplegic and paraplegic interaction with different kinds of devices, especially on how they interact and what kind of limitations they face.

3.3.5.1 Introductory questionnaire

In the first study session, during the collective interview, participants were asked to answer some questions regarding their current usage of computer and cellphone interaction modalities, as well as main difficulties while using computers and cellphones. The raw data regarding this small questionnaire can be seen in Appendix A, section A.2. In the remainder of this section, quantitative data will be presented and analysed regarding these participants.

Which interaction modalities have you used to interact with computers and cellphones?

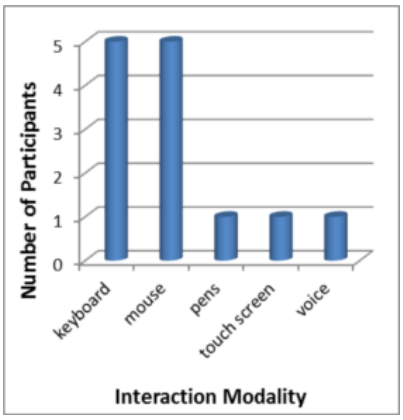


Figure 3.20: Previously used interaction modalities

As demonstrated in the previous section, overall, participants are used to keyboard and mouse interaction in their daily activities, which is clearly represented by the high rates of these modalities in Figure 3.20. Previous usage of voice, touch screens and pens to write on the keyboard, as alternative modalities is used in particular situations, and as such, interaction through these alternative modalities and others will be further analysed in the next section.

If you could use just one modality, which would you choose and why?

Figure 3.21 clearly shows that, due to several different degrees of physical limitations, as expressed in more detail on the questionnaire's raw data, participants are very keen on trying voice interaction. Over the second round of sessions, users were also very keen on trying out voice interaction, with quadriplegic users feeling that dictation and voice command & control, if done properly, would seriously improve their interaction with ICTs.

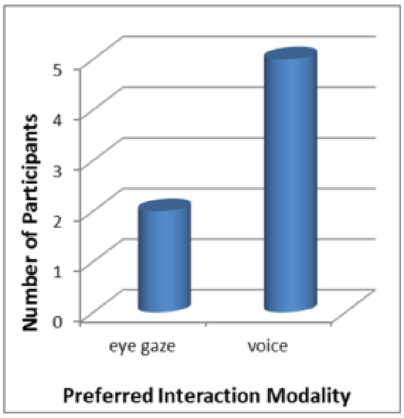


Figure 3.21: Preferred interaction modalities

3.3.5.2 Hardware Analysis

The previously described tasks focusing on social media services allowed the evaluation of user interaction with current interfaces such as the keyboard or mouse. To determine what kind of advantages alternative means of interaction can bring to mobility impaired users, and if they can even use specific modalities, a new set of tasks was devised to be carried out by the participants of the second user study session, as specific in table 3.3. The tablet PC specified in the previous section was used to conduct tasks related with speech interaction and digital ink recognition with a stylus, while a Samsung Omnia 2 I8000 running Windows Mobile 6.5 was used to evaluate interaction through its touch screen and built-in accelerometer.

After executing the hardware tasks, participants were asked to reply to the questionnaire in table 3.4

Scale B:

1 - Impossible to use
2 - Very Hard to use
3 - Hard to use
4 - Average
5 - Easy to use
6 - Very easy to use

Device	**Modality**	**Task**	**Observation**
None	Multitouch	Should the tablet PC screen be multitouch capable, could you use pinch and zoom or scroll gestures?	A multitouch screen wasn't available during either of the evaluation sessions, however, due to the possibility of usage of multitouch interaction in the final prototype, it was relevant to simulate this type of interaction.
Smartphone	3D Gesture	Try the *Dice Game*. Shake the phone.	This task focused on checking if participants had any issues holding a smartphone and operating its accelerometer while firmly gripping the phone.
	Touch + 3D Gesture	Try to start the game *Asphalt 4 Elite Racing*, *Resco Snake* or *Resco Bubbles* through the start menu.	In this task, participants tried to use the phone's touch screen through 2D drag gestures and touch screen selection, as well as playing a game through touch and 3D gestures. This task allowed perceiving if participants could properly control multiple aspects of the smartphone.
Tablet PC	Speech	Try to count from one to six	A simple application using MLDC's experimental European Portuguese speech recognition engine was used. This task focused on determining if mobility impaired individuals could properly use the ASR engine and if they could put a headset by themselves.
	Writing with digital stylus	Try to draw something on Paint. Try to write a sentence in English on Microsoft Word.	This task was conducted to determine if participants could use the stylus in an appropriate fashion and if they found it easier to use the tablet screen horizontally or vertically.

Table 3.3: Hardware usability evaluation tasks

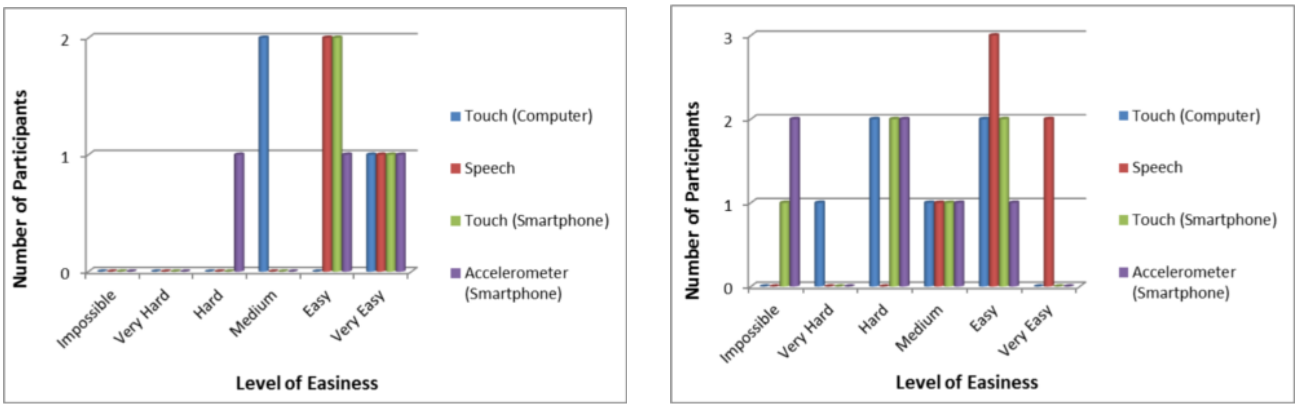
1.	Rank, according to Scale B, how easy/hard it is to use the following interaction modalities: a) Stylus writing on the table PC b) Speech interaction c) Touch interaction on the smartphone d) 3D gesture on the smartphone
2.	From the interaction modalities you just used, which ones did you enjoy the most?
3.	And the least?
4.	How would these modalities improve your daily interaction with ICTs?

Table 3.4: Hardware usability evaluation questionnaire

3.3.5.3 Results Analysis

The results presented in Appendix F.3 allow the division of all participants in this study into two distinct participant groups: paraplegic and quadriplegic individuals. Each of these two groups has different needs and modality usage restrictions.

As such, overall paraplegic individuals were able to use current modalities like the keyboard and mouse, as well as alternative modalities such as voice recognition, touch screens on both smartphones and desktop computers, and smartphone gesture control, without any significant issues. These participants noted that they would like to use alternative modalities, especially voice recognition, as a way to enhance their daily interaction with ICTs. Quadriplegic individuals, however, expressed many difficulties while using either type of interaction modalities. Regarding traditional keyboard and mouse control, the majority of participants interviewed used these devices very slowly, having to resort to one finger typing or their finger knuckles as alternative means of keyboard writing and, in the case of the mouse, they were either able to only partially hold the mouse, or had to hold it with both hands to assure better grip. Some, however devised alternative means, such as participant 2's use of pens or pencils to help him type faster. Regarding alternative modalities, overall participants found that the smartphone's accelerometer and touch screen required, in some cases, more precise movements, which some of the participants weren't able to achieve. Overall, however, quadriplegic participants found that speech recognition was easy to use, and would like to use it as a means to dictate text in their daily activities, but also to control their ICT devices. These results can be seen in Figures 3.22 and 3.23.



(a) paraplegic individuals' results

(b) quadriplegic individuals' results

Figure 3.22: Post-modality interaction questionnaire results

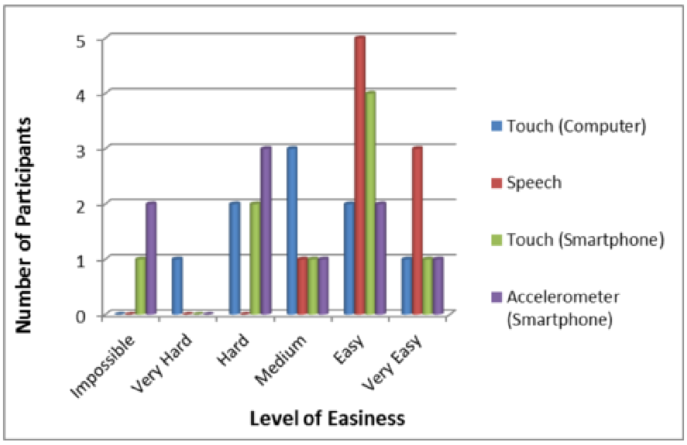


Figure 3.23: Post-modality interaction questionnaire results - Global Results

3.3.6 Summary

Both user study sessions conducted allowed the gathering of valuable information pertaining to user interaction habits and difficulties while using ICTs, SMSs and what they want a Social Media capable application to offer them. As such, they would like their ideal application to allow them to access both message based services and content based services, with focus on Facebook, Twitter, YouTube and Flick, but they would also like these applications to be usable with one or more modalities, depending on their preferences and limitations. Regarding the UI itself, they want these applications to offer large controls with minimum service specific jargon.

Chapter 4

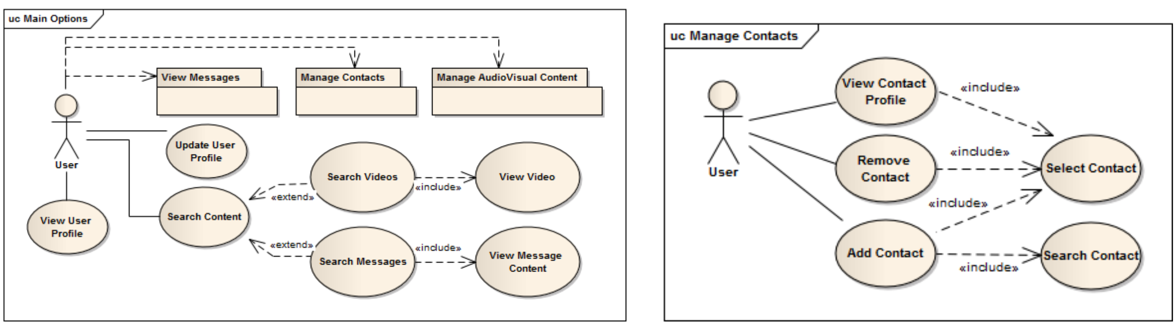
Multimodal Access to Social Media Services

The previous chapter presented the results of two requirements gathering sessions, conducted with mobility impaired individuals, namely quadriplegics and paraplegics. These sessions allowed the elaboration of a set of functional and non-functional requirements to understand what users wanted from the final prototype application, with regards to the UI, available modalities and supported SMSs. From these requirements an overall system conceptual and architectural model was elaborated. Both the former and latter are presented in the following sections.

4.1 System Requirements

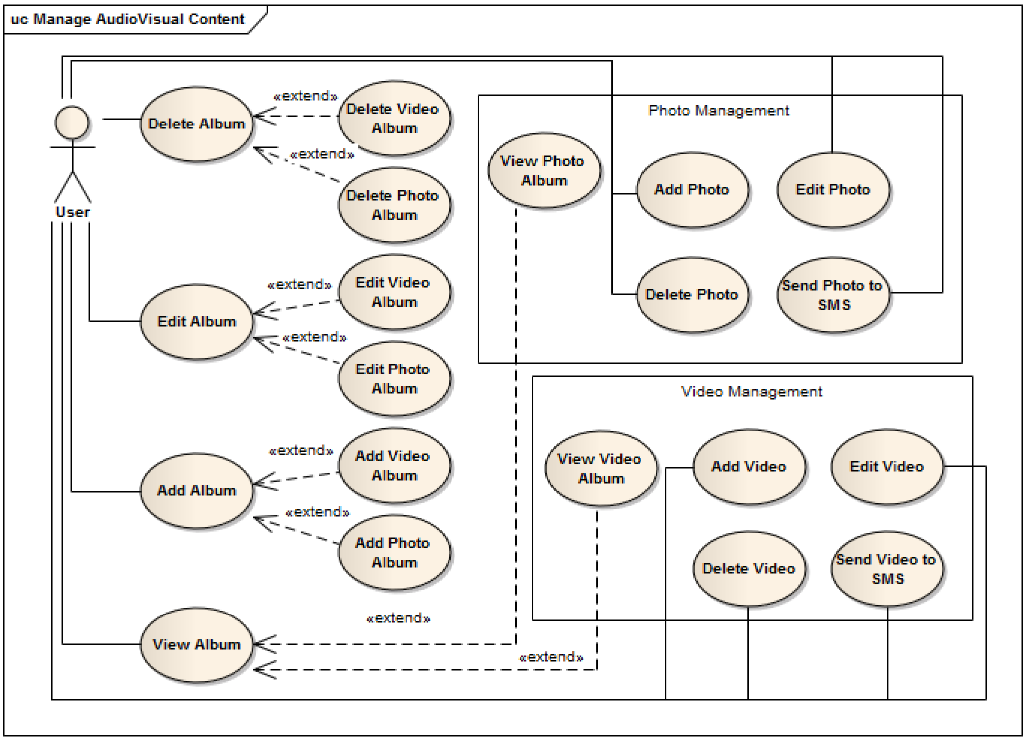
4.1.1 Functional Requirements

The following diagrams represent the proposed functional requirements for this prototype, elaborated in accordance to the functionality desires expressed by the study's participants. Detailed information on these use cases can be read in Appendix B.1



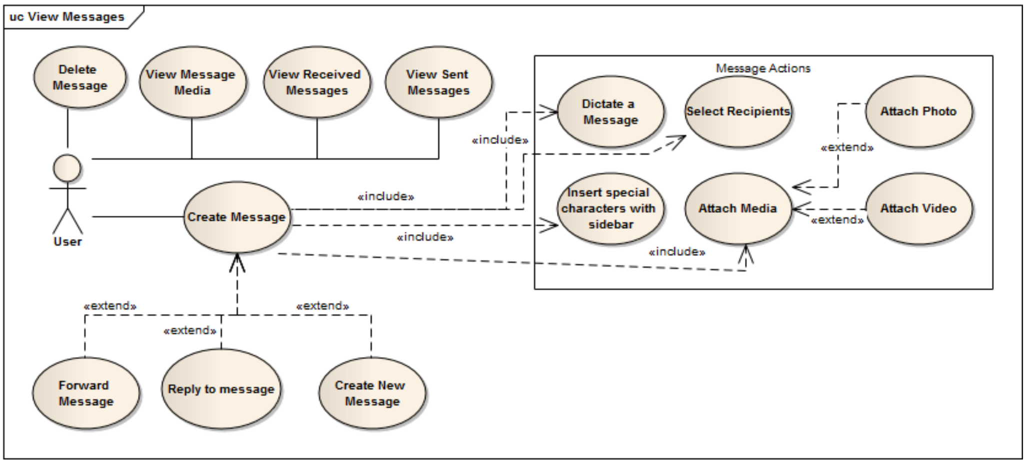
(a) Main Functionalities (b) Contact Management

Figure 4.1: System Use Cases (1/3)



(a) Audio Visual Content Management

Figure 4.2: System Use Cases (2/3)



(a) Message Viewing

Figure 4.3: System Use Cases (3/3)

4.1.2 Non-Functional Requirements

The system must be accessible to as many people as possible, with focus on increasing usability by mobility impaired individuals. As such, system development must take into account the following general HCI recommendations:

- Graphic icons should be large enough to be correctly used by both target groups, with special care for quadriplegics and additionally, shouldn't require precise movements and actions.
- The interface should be readable at some distance and must have not only large icons, but also large and clear text, that allows operation from fixed locations at some distance from the user, such as quadriplegics' wheel chair arms.
- GUIs must have simple text and a carefully chosen color scheme so as to have a high level of contrast.
- Multi-touch interaction should be carefully implemented so as to not become a usability barrier for quadriplegic users who aren't able to perform these gestures with ease.

The development of Mobile UIs must take into account the following recommendations so as to improve system accessibility:

- 3D gesture interaction should be carefully implemented so as to not become a usability barrier for quadriplegic users who aren't able to perform these gestures with ease or at all.
- Mobile interfaces must be designed to allow for easy usage while the device is fixed to a wheelchair's armrest.
- Mobile UIs should offer a feature set as close as possible to a desktop UI, to increase users' mobility.

The development of Desktop UIs must take into account the following recommendations to improve system accessibility:

- 2D gesture interaction must be carefully implemented, taking the same precautions mentioned for mobile GUIs.
- Touch interaction must be discouraged should the screen be placed vertically, to avoid the Gorilla Arm effect, as well as reducing the effect that the users' limitations have on this particular type of interaction, as was noted by the participants during task execution.
- As most quadriplegic individuals felt many difficulties using key combinations, these should be avoided. Should key combinations be needed, a special character sidebar should be available with large items, selectable by speech, touch or by picking with a regular mouse cursor.

Regarding social media services' UIs, the following recommendations should be taken into account to improve user experience with these services:

- Social media services UIs must be simple enough to use and not resort to service specific jargon.
- Social media services UIs should be carefully designed to have a low volume of information on each page/window to reduce user learning curve.

The development of the multimodal component of the system must take into account the following recommendations to improve accessibility:

- Interaction modalities should not be exclusive, but instead concurrent, so as to allow individuals to interact with their preferred means of interaction [HB06].
- Speech should be present in dictation mode to allow for easier input of large texts, thus reducing user stress.
- Keyboard and mouse interaction should always be present, allowing the execution of the same tasks as alternative modalities such as speech or gestures.

4.2 Summary

This chapter extended the information presented on the previous chapter and established concrete functional and non-functional requirements, based on the participants' input gathered during all initial requirements sessions.

With this input, it was possible to elaborate a somewhat vast list of non-functional requirements linked to accessibility issues. These requirements allowed us to conclude that participants want an integrated system that allows them to interact with all their daily social media needs, be they messages, content retrieval or media management, both local and remote. Participants expressed, however, that the system should offer them multiple means of interaction, in accordance to their preferences and limitations, be it conventional means, like the keyboard or mouse, or alternative means, like speech and touch. These means should, however, be concurrent, offering the same control possibilities, regardless of which modality is chosen by the user. Regarding alternative means of interaction like multi-touch or 3D gesture, some precautions must be taken so as to not make these means a usability barrier for quadriplegic users, as they are unable to properly use these modalities. As such, actions on the system must not be overly dependent on these means. Simpler alternatives must thus be offered for these types of interactions.

Participants also expect the system to have a clear UI with large icons and text, so that it can be easily used by both quadriplegics and paraplegics, be it in a desktop setting, where conventional UIs are deemed to require precise actions, something that quadriplegics aren't able to do with 100% efficiency, or in a mobile environment where, besides the need for large UI components is not only necessary from an action precision point of view, but also because most quadriplegics can only operate these devices when attached to a wheel chair's arm rest.

Another concern expressed by participants was the overall complex nature of some SMSs . This issue must also be taken into consideration while developing the UI, with the intent to reduce the overall learning curve.

With these concerns in mind, the following chapters present a more detailed view on the architectural and development choices concerning the prototype SDK and application developed over the course of two months.

Chapter 5

Software Development Kit

This chapter presents, in greater detail, the architectural and conceptual models of the software development kit (SDK) developed to support the prototype proof of concept application described in the next chapter. Technical and technological choices are also presented and justified as deemed necessary, to allow a more in-depth comprehension of why certain decisions were taken regarding the SDK development.

5.1 Architectural Model

The need for mobility expressed by the participants, coupled with the requirement for a portable system that can be easily installed in different kinds of systems with minimal setup overhead, led to two possible architectural choices. A centralized architecture, where every component in the UI, logic, and data storage layers would have to be duplicated over all desired platforms, or a de-centralized architecture. The latter was thus deemed more favourable than the former due to a lower overhead in development, deployment and client setup, as only a server-side component would be required to process speech (both synthesis and recognition), modalities and some of the core logic and data storage components such as SMS access, publishing and session maintenance between devices.

5.2 Technologies and Services

Regarding technological choices, due to the inherent collaboration between the author and MLDC's team members, a distributed server based solution, built on Microsoft's speech technologies, was considered a good option for the development of this work's prototype.

As such, the prototype's server side components were built on a solid Windows Server 2008 foundation, with resource to Microsoft's Office Communications Server (OCS) and its Unified Communications API (UCMA) as a way to establish a voice channel between a speech server running on a backend server, enabled with MLDC's European Portuguese (pt-pt) speech recognition and synthesis engines, and the frontend client device, be it a desktop computer or notebook computer. In this way, it was effectively possible to re-use voice and speech components in a distributed architecture, without the need for additional development. Due to some technical limitations regarding the in-existence of an application controllable OCS client on Windows Mobile, it wasn't at all possible to re-use these components to directly inter-connect windows mobile devices to the backend OCS server. As such, development of a simpler solution that resorts to audio file streaming to the backend through a web-service was needed.

Data storage on the SDK, be it user credentials and SMS setting, or media collections, is all done through a set of tables deployed in a Microsoft SQL Server 2008 instance running on the backend. To speed up data access on more frequently accessed data such as session keys to social media services and current SMS access state, this data is stored on in memory objects that are stored in disk when not needed as a way to maintain data persistence between client sessions.

To further simplify developers' work with the SDK, the majority of the system's logic layer is located in the backend infrastructure, thus reducing development duplication when using multiple platforms. Developers can thus access higher level speech services, and social media services through a simple, yet complete set of web methods running on five separate web services, which are respectively in charge of authentication operations with SMSs, user contact management and listing, message publishing and access, photo gallery management and video gallery management.

5.2.1 Social Media Services APIs

This section analyses in greater detail the APIs supplied by some Social Media Services, focusing on aspects such as functionalities, authentication schemas, client library availability, and communication architectures. These APIs were chosen due to the popularity of the services they encompass, as specified in Section 2.1. Furthermore, they represent the final choice of APIs. During the elaboration of this work several others were considered. These are described in greater detail in Appendix E.1 This section finalizes with an explanation of why a subset of these services was chosen.

5.2.1.1 Twitter

Twitter is defined as a social microblogging tool, allowing users to post short messages, with a maximum size of 140 characters, to a message feed. Users can use Twitter's social interaction functionalities to simply follow other users' feeds, forward messages to their own followers, called re-tweeting, send status updates or simply share their thoughts. Due to its nature, Twitter has grown beyond its own boundaries, from a simple service, into a complex social information network, allowing not only interaction through a web site, but through its API, thus creating an ever expanding application eco-system around its functionalities [Twi08a].

Twitter's API is currently separated into three distinct APIs, a REST search API, a REST data API and a streaming API. Efforts are however under way to unify both REST APIs. These require a developer to send HTTP formatted messages to one of multiple endpoints available, as defined in [Twi10h], specifying the API method to be called, parameters and response format, which can be XML, JSON, Really Simple Syndication (RSS) or Atom, depending on the developer's preferences and restrictions imposed by the API itself [Twi10g]. Some of the methods in the REST data API may require authentication, depending on whether they change any data on the backend or access private information. In those cases, Twitter supplies two different ways for a user to authenticate with the service and allow access to an application.

A more legacy method, which will be deprecated in Twitter's data API in the end of June [Twi10b], is Basic Authentication, where an application sends a user's username and password encoded in Base64, in the browser's headers. Due to the massive number of applications built around Twitter and this authentication model, migration to a newer solution is being made in careful increments, with the intent to not jeopardise user experience.

Since 2009, Twitter has been implementing an OAuth authentication schema, similar to Digg's current authentication model, divided into three variants: web authentication, desktop application authentication and an integrated solution called *Sign in with Twitter*. The web based authentication is very similar to Digg's implementation, requiring developers to register their applications with Twitter, thus receiving an API key and shared secret. Applications must redirect users to a Twitter page, sending along the API key. Here, users must log in and allow or deny access to their profiles. After the OAuth process, users will be redirected to a callback URL, defined by the developer, which will receive a token that can be used to make future authenticated calls to the API.

Sign in with Twitter is an authentication pattern based in OAuth that gives the user a more seamless experience, requiring in some cases just one click to authorize an application [Twi10e].

Desktop applications use a schema very similar to the web based one however, since there isn't any callback URL where to send the application's token, the process must be made out of band, with Twitter generating a PIN, that must be supplied, by the user, to the application, so as to allow it to retrieve a session token [Twi10a].

Besides these concerns, Twitter also imposes strict limits on the number of API requests that can be made hourly and daily, as well as on the size of result sets retrieved from the API, to allow better bandwidth control [Twi10g, Twi08b]. So developers can better control their usage, requests made to the API return information regarding current limit status on their headers. Certain measures, as suggested by Twitter, must be taken into account by developers to optimize API usage. These include data caching as well as prioritization of search queries and user activities [Twi10c].

Twitter's streaming API is a low latency, real time means of accessing and monitoring fast changing public data, such as links, tweets or re-tweets. Due to its nature, this API has several differences from the regular REST APIs. These include implied limitations such as only allowing access to information on public profiles, a maximum of one concurrent connection from an IP address and requiring the usage of Basic Authentication, or starting in June OAuth. Connection establishment and maintenance is also done differently. A developer must connect to an endpoint, authenticate, as already specified, and maintain an open connection to the endpoint, while receiving data in a constant stream. Since at peak hours data reception can be quite intensive, the official documentation suggests using multiple threads to allow better processing without data loss, with one thread dedicated to data reception and another to data processing. Streaming can also be done in one of two available formats, XML or JSON, with JSON being the recommended format, mainly due to it being more compact, but also because XML support is expected to be deprecated in the future [Twi10f].

As with most social media services, Twitter also supplies a list of unofficial client libraries, with which application developers can easily implement and deploy their software. As such, support exists for C++, .Net, Java, Perl, PHP, Python, Ruby, among others. In some cases, such as with Java and .Net, several different implementations of libraries exist. Since Twitter's API is constantly changing, library choice must be carefully made, so as to build around a solid foundation that evolves as the API does, but also, that supports the functionalities that are required [Twi09, Twi10d].

5.2.1.2 YouTube

Founded in 2005, and acquired by Google in late 2006, YouTube has become one of the most popular and widely used video sharing websites. Users can upload content, as long as it doesn't violate YouTube's terms of service, as well as create video playlists and channels associated with their service accounts. On a social aspect, users can also comment and rate videos, as well as subscribe to other users' channels, thus following their video posting activities.

YouTube's developer tools are divided into five different kinds of APIs and tools. Their Data API and Player API allow developers a more refined control over exactly what content to show and how to interact with the backend service, making it possible to search, upload videos, create playlists as well as controlling an embedded video player that lies in a web page or web control. YouTube also supplies higher level components such as their pre-built players, widgets and the YouTube Direct tool, all of which allow quick deployment of YouTube content and service interaction in web sites, without the need to directly use any API. For the purpose of this thesis, more focus will be given to the Player and Data APIs [Inc10g].

The Data API works through Google's Data Protocol, which is in essence a RESTful derivative way of interacting with their backend service, allowing read, write and update operations on several Google services, in an unified way. Requests are made using regular HTTP commands, and replies can be returned in either an XML syndication feed dialect called Atom or in JSON [Inc10x]. Data search can be done by simply issuing a request towards the Google Data endpoint, as described in [Inc10i], which will return data formatted either as an Atom data feed or a set of JSON objects. This API also allows developers to access and manipulate users' private data, such as their profiles, contacts, video messages, playlists or video ratings. These operations require the user to authenticate with YouTube's backend service, since they either access or change user specific data [Inc10v, Inc10n, Inc10p, Inc10r, Inc10s]. Three other operations that require users to authenticate with the service are video upload, video metadata manipulation and video deletion. The two latter operations only require the application to issue a REST command to the API, as specified in [Inc10t]. Video uploading can be done in two different ways, either through a web browser or directly to the API. In the first approach, an initial request must be done to the API, so as to send the video's metadata and retrieve an upload token. The developer must then show a web form to the user, which can be used to upload the video to YouTube. With direct uploading, an application must send an authenticated POST request to the endpoint, specifying in the same request the video's metadata and its binary content [Inc10u, Inc10o, Inc10l].

Authentication is supported by the YouTube API via one of three different procedures: AuthSub, OAuth or ClientLogin. The first two are more adequate for the development of web applications, while ClientLogin usage is recommended for the development of standalone desktop applications [Inc10j]. OAuth authentication works just as described in previous APIs, with the caveat that it does not support out of band authentication, and as such, isn't appropriate for desktop applications [Inc10q]. AuthSub is a Google specific authentication method, very similar to OAuth, where the application must first request an access token, through a call to the API. This token will be supplied to the application, should the user log in to the service and authorize the application, and can be used once. Developers can use it to make a single authenticated call to the API or can exchange it, through another call to the service endpoint, with a session token, which can be used to make successive calls to the API [Inc10k]. ClientLogin is a simplified authentication method, where users must supply their login credentials to the application. These can then be used by the application to request an access token to YouTube's authentication service. In some cases, should the backend service require, the user may also need to answer a CAPTCHA test, supplied by the endpoint, the answer of which must be supplied inside a new token request made by the application [Inc10m].

To simplify the interaction process, official client libraries that abstract this whole process are supplied by the Google Data team in the following languages: Java, .Net, PHP, Python, Objective-C and JavaScript [Inc10h].

Since YouTube's content access is strictly controlled, developers who want to display videos on their applications must embed the YouTube player in a web page or web component on an application. Two kinds of players are supplied: the standard YouTube player, and a *chromeless* variant, that omits interface elements, such as the control bar and player borders, allowing a better integration of video playback with alternative page designs. The embedded player can be controlled through a JavaScript player API, supplied by Google, that supports video queuing, playback control, playback status querying, as well as events regarding player errors, and playback changes [Inc10g, Inc10y].

5.2.1.3 Summary

The in-depth analysis made on the previous sections demonstrates several key points on SMSs' APIs and means of development. Figures 5.1 and 5.2 thus summarize this information, focusing on development formats, client libraries, authentication schemas and API types, with the intent to show where these APIs converge and diverge.

Social Network	Domain	API	Formats	Functionalities	Platforms	Environments	Authentication
YouTube	Video sharing	Data Query and Update	REST (ATOM, JSON)	Contacts, Messages, Playlists, Profile, Ratings (query and manipulation) Video Upload and Deletion	Desktop	.Net, Java, Objective-C, Python	ClientLogin
					Web	.Net, Java, JavaScript, Python, PHP	OAuth, AuthSub
					Mobile	.Net (Win. Mobile), Objective-C (iPhone)	ClientLogin
		Video Playback	JavaScript	Video Playback control and status querying	Desktop	JavaScript	N/A
					Web	JavaScript	N/A
					Mobile	JavaScript	N/A

Figure 5.1: Social Media Services API Comparison (1/2)

Social Network	Domain	API	Formats	Functionalities	Platforms	Environments	Authentication
Twitter	Micro-blogging	Data Query and Update	REST (XML, JSON, RSS, ATOM)	Friend, Status, Timeline, Tweet, User (query and manipulation)	Desktop	.Net, C++, Java, Objective-C, Python	OAuth, Basic Authentication
					Web	.Net, Flash, Java, Perl, PHP, Python, Ruby	OAuth, Basic Authentication
					Mobile	.Net (Win. Mobile), Objective-C (iPhone)	OAuth, Basic Authentication
		Search	REST (XML, JSON, RSS, ATOM)	Searching Tweets and Trends	Desktop	.Net, Java, Objective-C, Python	N/A
					Web	.Net, Flash, Java, Perl, PHP, Python, Ruby	N/A
					Mobile	.Net (Win. Mobile), Objective-C (iPhone)	N/A
		Streaming	Data Streaming (XML, JSON)	Monitoring Links, Tweets, Re-Tweets	Desktop	.Net, Java, Python	OAuth, Basic Authentication
					Web	.Net, Java, PHP, Python	OAuth, Basic Authentication
					Mobile	.Net (Win. Mobile)	OAuth, Basic Authentication

Figure 5.2: Social Media Services API Comparison (2/2)

5.2.1.4 Service Choice

Regarding social media service selection to include in the prototype, as per the participants' expressed preferences, YouTube was chosen as the primary video service where to retrieve and publish videos. As such, the SDK currently supports basic YouTube features like video search, viewing and publishing. Although Facebook was noted as the most known and preferred message based social media service, due to technical limitations with the REST API at the time when development began, mostly related with limitations in content publishing, notably private messages, photos and videos, and the inability to search information from a third party application, it wasn't selected as the message service for this SDK. Twitter and its attached services (Bit.Ly, TwitPic and TwitVid) were thus selected to supply messaging and contact functionalities to the SDK. As shown later, however, this is a not a limitation towards future development, as the logical component architecture was devised to be modular, so that developers can extend the SDK with support for other messaging, video and photo services, as deemed necessary.

To support YouTube API access while re-using pre-exiting code, the official YouTube .Net SDK [Inc10w] was used, however, a small abstraction layer over this API was developed to simplify access through web services, with most actions only requiring the developer to call one method on the web service to retrieve or publish data from/to YouTube.

Due to Twitter's constant API changes and large number of client libraries [Twi09], a more thorough analysis of supported features and active development was needed so as to avoid shortcomings in the library during active development, and also to avoid unstable application functionality during active development of the SDK and the prototype application. As such, after careful analysis, TweetSharp [Cre10] was selected due to its matureness (over 1.5 years of development), active level of support and large feature set. It was also the only .Net library to currently support OAuth, which was a decisive factor, since Twitter is removing Basic Authentication support in June [Twi10b]. As with YouTube, a small abstraction layer was built on top of this library to minimize developer learning curve, requiring the usage of a simple set of web methods to authenticate and interact with Twitter's API.

To support Twitter's attached services, three additional libraries were used and abstracted using web methods. Bit.Ly support, to allow developers to shorten large URLs, so they can fit Twitter's 140 character limit per message, was added using a small wrapper developed in C# [Sny09]. Image storage with support for url shortening was added through TwitPic, using the simple TwiPLI C# wrapper [Tom09], which was also abstracted through the use of web services. Due to some issues with the YouTube .Net SDK's upload feature, video storage and video url shortening features were added through TwitVid, using a custom made C# wrapper.

The following sections present, in greater detail, the SDK's physical and logical platform architectures, to further consolidate the integration between the previously described technologies and services.

5.2.2 Physical Architecture

As already mentioned, to allow for better code re-usage and separation between the front-end UI and logic components, and the backend logic components, thus allowing for better code maintenance and portability through inherently different platforms as Windows mobile and the Windows desktop are in terms of UI development paradigms, a distributed architecture was devised, as shown in Figure 5.3.

In this architecture the proposed clients are Windows Mobile devices, desktop computers and touch screen enabled computers. These devices all act as front-ends, possessing all the UIs and control methods, and a minimal logic layer that translates UI actions into remote invocations over web services offered by the PLA Server shown in Figure 5.3, as well as action requests sent by the PLA Server into local UI actions, such as requests made through voice control. The PLA Server contains all logic components used to interact with SMSs and issue remote UI interaction commands, as well as some speech interaction components such as the desktop and mobile speech servers, described in more detail in the next section.

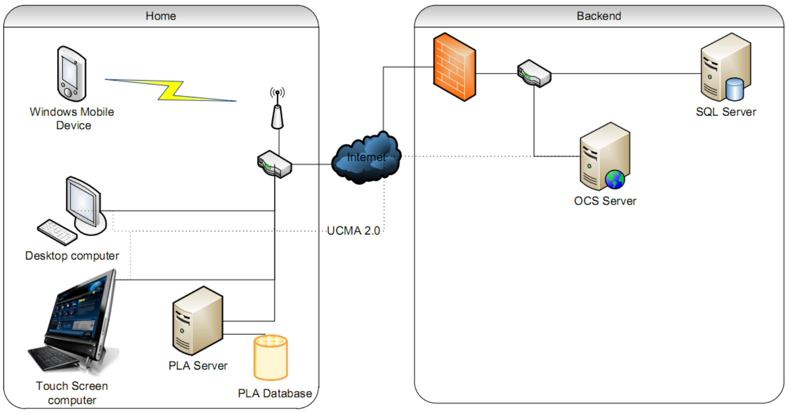


Figure 5.3: Physical System Architecture

Should the requests be made to operate only on SMS data, such as messages, images or videos stored on-line, or local data such as local images or videos, the PLA Server can directly interact with this content, without resorting to any of the backend services.

Requests that require speech processing, be it synthesis or recognition, require the PLA Server to communicate with a backend OCS server that in turn requires access to a SQL Server database to retrieve user account information regarding the connecting client. Speech or text data can then be sent from the client device to the OCS Server via a SIP stream. The OCS Server will in turn reply with respectively a recognized string to the PLA Server or a voice stream to the client device, with the result of the speech synthesis process.

5.2.3 Logical Architecture

Following the previously presented physical architecture, the next diagram presents a more logical view of the system, showing how all developed components interconnect.

As can be seen in Figure 5.4, two main connection endpoints exist that connect clients to the backend server: the logic web service and a speech server, both of which are contained inside the PLA Server.

Regarding the logic web service, as already mentioned, this module is used to supply the client with data from SMSs, as it is requested, be it contacts, messages, videos, photos, as well as publishing data to the SMS. Towards this, the web service uses a set of libraries and wrappers, as previously explained, which in turn interact with SMS APIs mainly through HTTP REST Requests and Replies. This end-point is also used by clients to start and maintain a session on the PLA Server, which in turn maintains all sessions to SMS services that have been pre-registered on the user's account stored in the PLA Server's

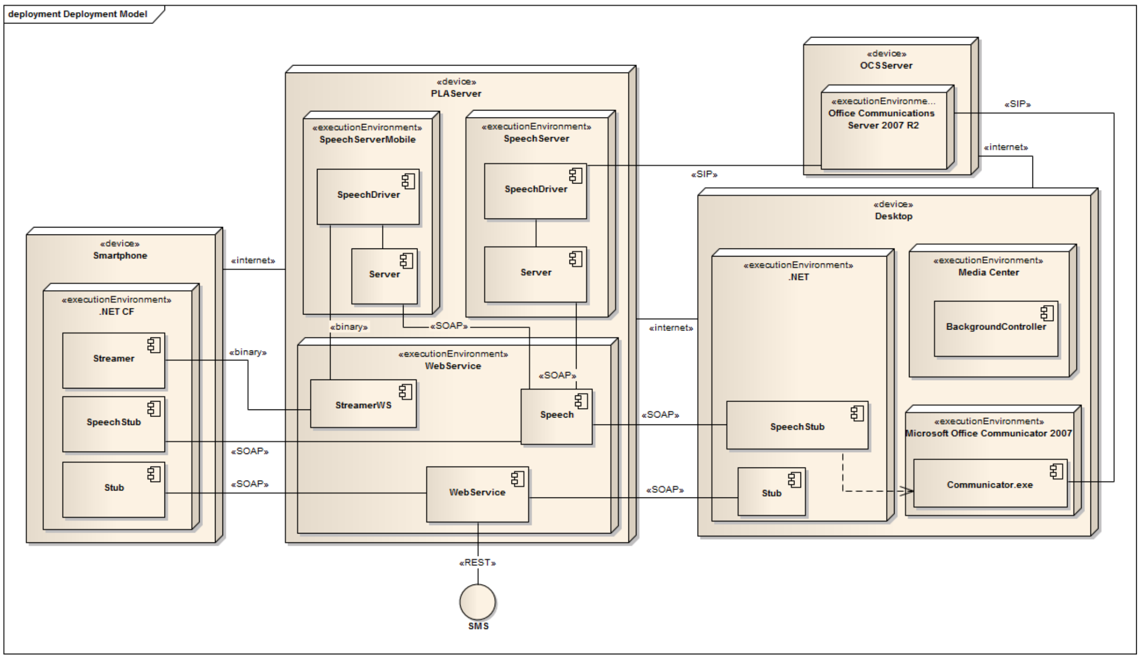


Figure 5.4: Logical System Architecture

Database. All communications with the PLA web services are mediated through a stub on the client device, as shown in the diagram.

The speech server is divided into to two different modules, depending on whether the client device supports or not voice communications via an Office Communicator Client or the Unified Client Communications API (UCC API).

Should it support, as it happens with the Desktop device, then a Speech Server stub simply needs to establish a SIP a call to the speech server running on the PLA Server, using the backend OCS Server. All voice communications with the speech server will then be made via this channel. To perform speech recognition, the speech server will receive an audio stream and, using the Unified Communications Managed API 2.0 (UCMA), will perform speech recognition using the selected engine. Results of this process will then be sent to a queue running on the Speech component, in the web service, which in turn will be emptied by the client on regular polling intervals. Speech synthesis works with simpler reversed process. The client invokes a web method running on the Speech web service, which in turn populates a queue with pending text. The *SpeechServer* will poll this web service for new messages, which will be submitted to the speech synthesis engine. The result will then be sent to the client via the previously established SIP channel.

When the client doesn't support the Office Communicator client, UCC API or the Office Communicator Automation API, the latter of which allows external applications to control the Office Communicator client, then it's necessary to resort to a different kind of audio streaming. This is the case with Windows Mobile. To solve this issue, the Windows Mobile client sends recorded WAV files with a variable size to a queue running on a web service, called the *StreamerWS* in the diagram. This queue is then consumed by the *SpeechDriver* on the *SpeechServerMobile* environment, which in turns submits the WAV file to the speech recognition engine. The result of this process is then sent to a queue on the Speech web service, as happens the previously described process. The speech synthesis is very similar to the Desktop based synthesis, with the only difference being that the *SpeechServerMobile* server will send the resulting binary voice data to the original web service, which will then be consumer by the device on a regular polling cycle.

5.3 Relational Model

The following diagram shows the SDK's relational model used to store credential and media data.

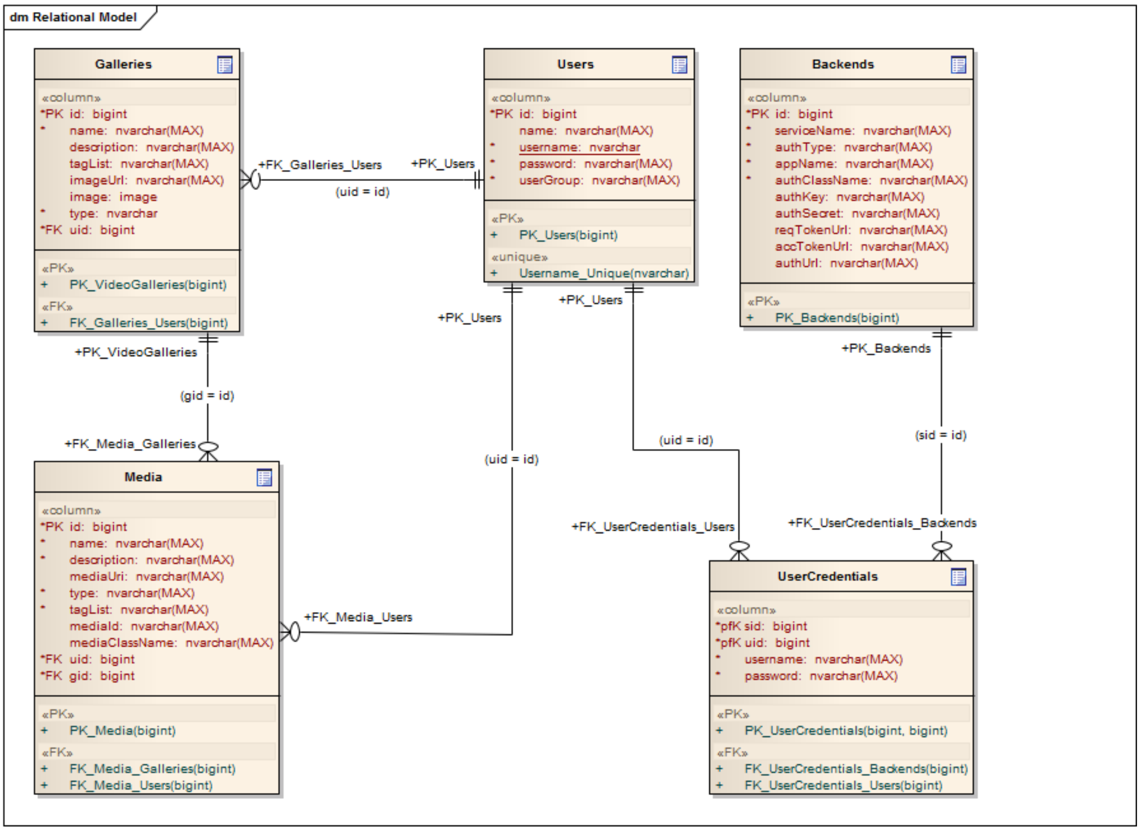


Figure 5.5: Backend relational model

In the model presented in Figure 5.5, table *Galleries* is responsible for storing all video and photo albums, having the ability to store the Uri to a representative image of the album or the binary data of the image itself. Table *Media* stores the metadata of the actual photos and videos as well as information on where to retrieve the actual media content, be it the full media's URI or simple media ID that can media used by the media's representative class to actually retrieve the media.

Regarding authentication, the SDK was conceived from the beginning to support multiple services and users. As such, system users must first be input into the *Users* table. These can then be associated to one or more registered SMSs, which must be registered in the *Backends* table, by storing service credentials in the *UserCredentials* table. Due to the existence of different authentication schemes, according to the SMS used, the *Backends* table contains different fields that must be filled in accordance to the selected authentication method, so that the registered authentication class can properly process the users credentials. Currently the model was conceived to support Basic Authentication, Client-Login and OAuth, as these are the required authentication models for the supported SMSs.

5.4 The SDK

This SDK was built with the purpose of developing de-centralized applications, with most, if not all, of the application's core logic located on a backend server. Developers can access this logic through a set of web methods deployed on one or more web service servers. As most web methods require access to some sort of user specific data, such as user photos, videos, messages, contacts, etc, developers must first supply the authentication web service with system wide credentials. If valid, the web service will supply the application with a Globally Unique Identifier (GUID). This GUID can then be used as a token to access user specific data.

To access the SDK's speech functionalities, developers can either implement their own means to interact with the Office Communicator client, be it through the Automation API or any other way, as well as a means to interact with the speech web services, or they can use the window manager and custom programming interfaces described in the next chapter, as a means to further simplify the development of OCS speech enabled applications.

The developed SDK can also be extended, as desired by the developer, to support newer services. As such, the SMS component of the SDK contains several interfaces that allow the support of newer means of SMS authentication, contact management, message publishing/reception, photo management, video management, as well as new media types. Developers need only to add new classes that implement the supplied interfaces, in pre-specified location, and the SDK will take care of searching for these classes and executing the required methods.

5.5 Summary

This chapter presented the SDK's overall architecture and data storage model, as well as a more in-depth insight into which technologies were used, why, and how developers can extend this SDK to their own applications.

The modularity of most of the SDK's components, be it with regards to the supported SMSs, speech components or modalities, makes this a powerful platform for the development of not only applications that access SMSs, but also that access other kinds of on-line services. The close integration between mobile and desktop environments, although still not incomplete due to the current inherent unsynchronized nature of the interaction in these platforms is still, however, a shortcoming that must be addressed in future iterations of this SDK, to actually provide a seamless experience while developing for multiple platforms.

Although server side multi-modality wasn't built with a true fusion engine, it is still possible for developers to build their own multimodal applications using this SDK, as will be shown in the next chapter, which describes a multimodal proof of concept application developed with this SDK. The SDK can, however, with further work, support a true fusion engine, as most of the components, such as, recognition grammars, command to action mappings and a client library for the Extensible MultiModal Annotation (EMMA) W3C markup language [W3C09] are already supported by the SDK.

Chapter 6

Proof of Concept Application

Using the SDK described in the previous section, a proof of concept application was developed. Besides following the functional requirements specified in Chapter 4, in an attempt to make the application as close as possible to feature complete, special precautions were taken to follow, not only the non-functional requirements elaborated from the study's participants' feedback, but also to follow, as much as possible, accessibility standards.

6.1 Prototype Mockups

During the initial stages of the prototype specification, a set of low fidelity mockups were developed to better structure the overall navigation flow of the application, and to also define the overall look of the application.

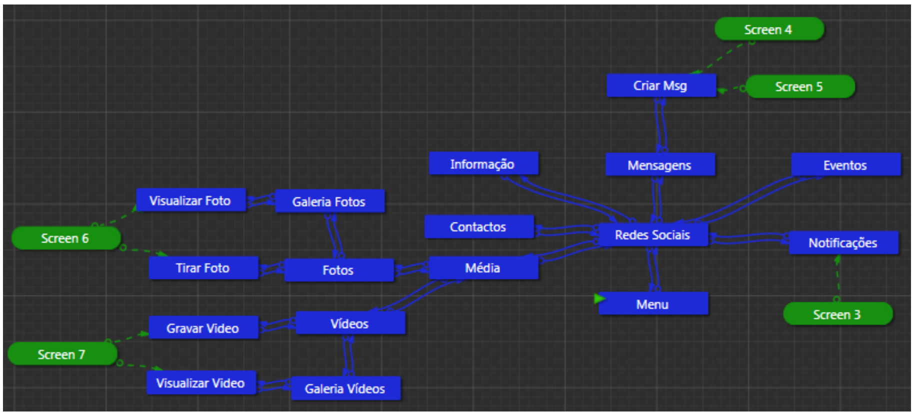
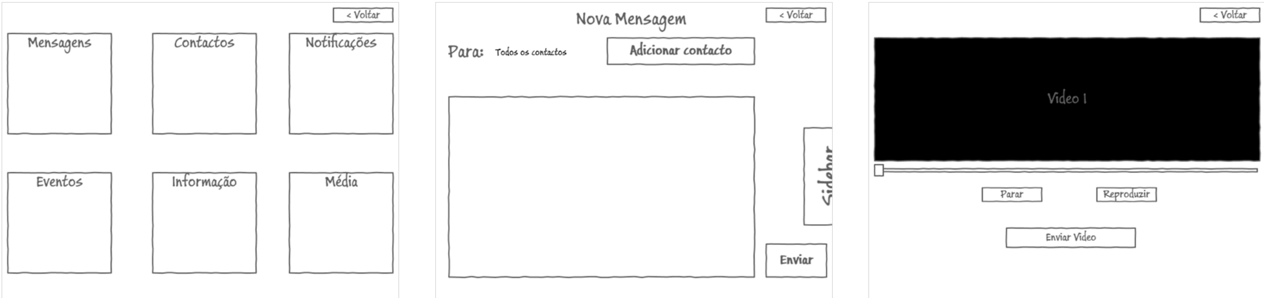


Figure 6.1: Mockup UI navigation flowchart

As can be seen in Figure 6.1, all base features have been prototyped using a rough model from the initial mockup diagrams. As such, support for messages, contact management, videos and photos has been thought out since the initial prototyping stages.



(a) Main Application Menu Mockup (b) New Message Mockup (c) Video Player Mockup

Figure 6.2: Prototype sample mockup screens

Accessibility improvements like the use of large buttons, large text, the availability of a special characters' sidebar, use of simple text without technical jargon, among others recommendations specified in chapter 4, have been a concern since the early prototyping stages, as can be seen in Figure 6.2. The remainder of these low level mockups can be seen in Appendix C.1

6.2 Technology Selection

Although any UI technology whose underlying programming language and frameworks support the Web Services Description Language (WSDL) could have been used for the development of this prototype application since the majority the application's logic layer code is accessible through a web service, due to past experience with Microsoft UI development technologies, more specifically Windows Forms and the Windows Presentation Foundation (WPF), these technologies were chosen. In the desktop platform, WPF was chosen due to it being a more recent and powerful UI development platform, having used features such as component animation through storyboards, user controls, a vast collection of user controls available on-line that allow for a more pleasant user experience, as well as a more fine control over how the UI is developed, with the possibility to use refined control containers like grids, stack panels, among others. To allow for a more powerful development experience, most of the UIs were developed using Microsoft's Expression Blend. In the mobile platform, the only choice was to use Windows Forms for Windows Mobile, as the smartphone used, a Samsung i8000 Omnia II running Windows Mobile 6.5, only supports this UI development platform. To support additional interaction modalities like the device's accelerometer, orientation sensors and haptics, the Samsung Mobile SDK was used, thus giving access to advanced device specific APIs. To develop the logic integration components, the .Net 3.5 Framework with the C# programming language was used.

6.3 The Prototype

Developed in parallel with the logic components in the backend PLA Server, this prototype applications consists of two applications developed, respectively, for the Windows desktop and Windows Mobile platforms. Both prototypes were developed with service integration in mind. As such, both the desktop and mobile UIs, as well as the backend logic core support Social Media Services' interaction, the focus of this dissertation work, but also e-mail, conferencing and agenda management, all integrated into a single unified UI. e-mail, agenda and conferencing will not be covered in this thesis, and can be viewed in more detail in [dNTGP].

6.3.1 Desktop Prototype

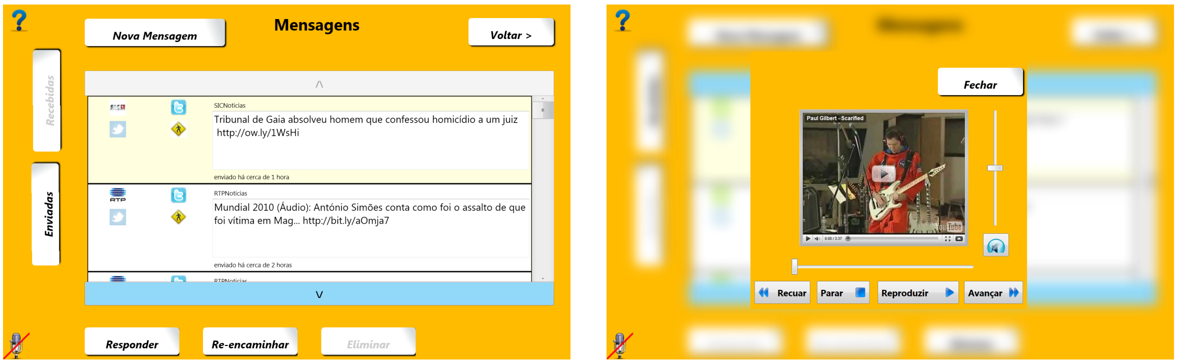
This prototype was developed in accordance to the users' functional and non-functional requirements, following some of the previously presented mockups' structure. This UI was developed with multi-modal input/output (I/O) in mind, and as such, simple touch, speech, keyboard and mouse input is fully support in all windows, thus allowing users to interact with their preferred modality, as they are complementary. Multi-touch interaction is also supported, although only while viewing photos contained in any photo album. Output is also available through either displaying the content on the device's screen or through speech synthesis, be it through simple text prompts or full text readers, as what happens while viewing SMS messages.

(a) Main Application Menu

(b) SMS Main Menu

Figure 6.3: Prototype menus

As can be seen in Figure 6.3, one of the major concerns while developing this prototype was to use large buttons with clear text and representative icons, that are easy to touch, even by quadriplegics who are unable to precisely hit a section of the screen with their hands. Should the user desire, all buttons can be triggered by mouse input or speech, the latter by saying the name of the desired button.

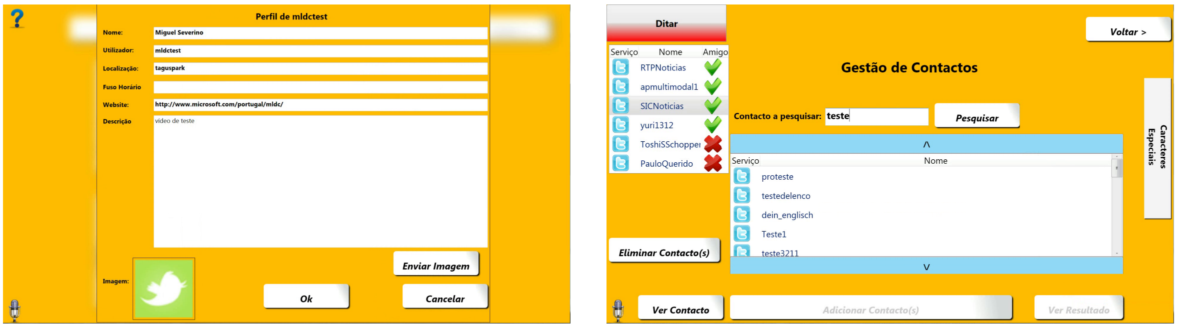


(a) Messages Listing UI

(b) Message Video Player

Figure 6.4: Prototype menus

The messages UI was designed to closely resemble Twitter's timeline however, action buttons were also replaced with larger buttons that can also be triggered through touch, mouse or speech, as can be seen in Figure 6.4(a). Users can also navigate messages through either of these modalities and view their content, be it a link to a web-site, an image or a video. The video player can also be controlled through touch on either the regular player interface, using the larger control buttons on the video window or through voice, as can be seen in Figure 6.4(b).



(a) User Profile window

(b) Contact Management window

Figure 6.5: Forms

Form filling works as with any regular form on a conventional application. Special care has been taken, however, to enlarge labels and text on form fields, as well as buttons, as much as possible. Users are, however, able to select fields through touch, mouse interaction or speech, the latter of which, by simply saying the name of the desired field's label. When an editable field is selected, the user can fill it either by using a hardware keyboard or, if supported, through a virtual touch keyboard or through speech. To support that latter of these methods, users can expressly enable a dictation text entry mode, the output of which will be passed to the application by the speech server. This can be seen in Figures 6.4(a) and 6.5(b).

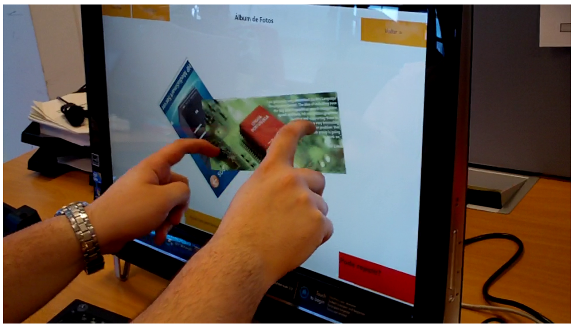
(a) Photo Album

(b) Video Album

Figure 6.6: Albums

Both video and photo albums support an easy to use 3D coverflow mode of previewing media, as can be seen in Figures 6.6(a) and 6.6(b).

(a) Multi-touch screen interaction (in the application)



(b) Multi-touch screen interaction (with the touch screen device)

Figure 6.7: Multi-Touch Photo Album

As already mentioned, photo albums also support photo viewing in multi-touch mode. This interaction can be seen in Figures 6.7(a) and 6.7(b).

Other screen shots portraying additional features of the prototype's desktop UI can be viewed in Appendix D.1.

6.3.2 Mobile Prototype

As with the desktop prototype, the mobile prototype application was also developed in accordance to the users' requirements, with larger focus being given to issues such as the usage of large buttons whenever possible and overall application control through voice, motivated by interaction limitations observed during the pre-development sessions already presented. These concerns can be observed in Figures 6.8(a) and 6.8(b).

Control of lists such as the one in Figure 6.8(c) through use of the accelerometer is also possible, should users desire it, although control over scrolling and selected items can also be achieved through voice or touch.

When larger forms, such as the one in Figure 6.8(d) are presented, it's possible to select fields either through touch, by tapping the selected field, or through voice, as with the desktop prototype. Due to technical limitations, however, dictation isn't currently supported in the mobile version of the prototype application, and as such, users must use one of the several supplied software input panels (SIP).

As with the desktop prototype, other figures portraying additional features of the prototype's desktop UI are available in Appendix D.1.

(a) Main Application Menu (b) SMS Main Menu (c) Opened Options Menu (d) User Profile

Figure 6.8: Mobile Prototype menus

6.3.3 Standards Compliance

One of the main concerns while developing any of the two prototype applications (desktop and mobile), was to make it as accessible as possible, following not only the specified accessibility non-functional requirements, but also already established accessibility standards such as Section 508 of the Disabilities Act. As such, technical standards such as the ones defined in Subpart B 1194.21, on Software applications are followed. These include, but are not limited to, compliance with points c, e or l of this subpart, allowing users to use supported assistive technologies to interact with the application, maintaining a consistent meaning of icons and images throughout the application as well as showing a clear representation of the currently focused element, a concern that was also considered while developing dictation text insertion [Boa00].

Some concern was also taken to support some of section 508's revised draft version's guidelines. These include, but are not limited to sections 307.4, 307.5, 307.6, 402 or 403. These sections focus thus on supplying alternative ways to control the devices without requiring too much strength or a tight grip on the device, tactile discernibility while operating the device to distinguish tactile controls, even without activating these, supplying alternative ways to touch while operating the device, such as voice or gesture, among others [Boa10].

6.3.4 Technical Considerations

Developers using the previously described SDK are able to seamlessly access all the supplied features through any of the several supplied web service endpoints. To simplify this interaction, however, especially with regards to all the speech server interaction process, as described in the previous chapter, four components were developed, two on each platform, that can help simplify the development effort, thus promoting code reuse. On the desktop platform, developers can use the supplied PLAWindow programing and PLA window manager, the latter embedded into the application's main class. With these components it becomes very easy to implement multi-modal enabled applications, with the majority of the work behind enabling speech recognition and synthesis on the client, enabling grammars on the server in accordance to the client's current state or enabling full speech control of one or more windows, now being done by these components.

On the Windows Mobile platform, speech integration has also been developed and abstracted away to minimize development effort. One limitation though, is that developers must send and receive speech with resource to wav files. This made it difficult to properly implement dictation support in the application, and as such, voice interaction is only supported in command and control (C&C) mode. This process has, however, been abstracted with resource the mobile platform's window manager. This window manager also supports managed code access to the Windows Mobile device's specific APIs, in this case, to Samsung's hardware specific APIs.

6.4 Summary

This chapter presented two proof-of-concept applications developed on the Windows desktop platform and Windows Mobile platform, using respectively WPF and Windows Forms as UI development paradigms and the .Net framework to support core logic components and backend web service interconnection.

Special care was taken to support, as much as possible, existing accessibility standards, as well as UI development recommendations gathered from participant input. As such, it was possible to fulfil all non-functional requirements, supporting large significant icons, large text on both buttons, labels and form elements, and multi-modal I/O, thus allowing users to interact with the application components with whichever supported modality they desire.

By using the previously described SDK it was also possible to build not only a set of prototype applications, but in reality, two platforms that allow the easy development of multi-modal I/O supporting applications, allowing input through conventional means, like keyboard, mouse, touch or speech recognition, as well as output through visual content display or speech synthesis, be it through simple prompts or full text synthesis.

Chapter 7

Usability Study

Using the prototype applications described in the previous chapters, a third study with mobility impaired users was conducted during one week in June, with five participants who had already taken part in the previous user study session, to evaluate the prototypes' usability from mobility impaired individuals' perspectives, as well as determining if the participants found any benefits in using this multimodal interaction approach as opposed to the traditional means of interaction supplied by common application, such as the keyboard or mouse.

In the beginning of each individual session, the study's goals were explained to the participant. Like in the previous study sessions, audio and video was recorded for further analysis.

Participants were asked to perform a set of tasks focusing on contact management, user profile manipulation, message viewing and publication on Twitter, as well as searching and viewing videos in YouTube and managing local photo and video galleries composed of local and remote videos published in YouTube. In the end of the task, participants were asked which difficulties they felt during the task, what they would improve in the feature they just used and why they had used a specific modality or set of modalities in detriment of others available. At the end of the session, participants were asked to answer a short questionnaire, the results of which are available in detail in Appendix A, section A.4, to better evaluate the overall opinion of the participant on the prototypes tested, with regards to the modalities used in this specific context and how would the prototypes improve his/her daily activities.

In the following sections, a more in-depth analysis is made on the data gathered over this study, with the intent to better understand how these prototypes actually improved participants' interaction with Social Media Services and what shortcomings were felt by the participants.

7.1 Study Participants

As with previous study sessions, mobility impaired individuals who took part in these sessions were recruited from members of Associação Salvador, who kindly provided the contacts of some of their members who were interested in taking part in these activities. These participants were selected from the second session's participants, to be able to compare their previous results with current results. Due to time, displacement limitations, and participant availability, we were only able to recruit five of the previous ten participants to this study, namely, participants 5, 7, 8, 9 and 10 from the previous studies. Nonetheless, the results were very positive and a large amount of information was gathered. A control participant was also used as a means of comparison. This control participant was a female 25 year old assistant product manager.

7.2 The Evaluation

Tests were conducted in a quiet, calm and controlled meeting room environment. The same hardware was used with every user, as specified below, and before task execution, the test account previously used in other sessions was reset, to guarantee that no side effects from previous accesses appeared during the test. All participants were interviewed individually.

7.2.1 Hardware and Software

A touch-capable PC was used with the following specifications:

- HP Touchsmart 600 Quad
- Intel Core i7-720QM at 2.8 Ghz
- 4 GB RAM
- Wireless mouse and keyboard
- Integrated webcam and mic
- Windows 7 Home Premium 64-bit
- Internet access: ethernet
- Browser: Internet Explorer 8 or Mozilla Firefox 3.6 (depending on user preference)

To test the mobile prototype application a Samsung Omnia 2 I8000 smartphone running Windows Mobile 6.5 was used.

The backend web services and communication services were operated from a physical hosting server running two virtual machines powered by Windows Server 2008 R2. One of the virtual machines was running the several web services, used to operate the application's logic layer and speech server interaction web services, on top of Microsoft's Internet Information Services (IIS) 7.5. The other virtual machine was running Office Communications Server 2007 R2, as well as two daemons, respectively responsible for speech synthesis and recognition on the mobile and desktop platforms. Speech recognition in command and control mode and speech synthesis was done using Europe Portuguese (pt-pt) engines developed by the Microsoft Language Development Center (MLDC) over the Unified Communications Managed Speech API. To enable text dictation support, an early development dictation model, also developed by MLDC, was used. This limited, to some extent, the positive opinion that some participants had during the evaluation, as will be further expanded during the next sessions.

7.2.2 Tasks

Participants were first shown how the application worked, in general terms, to reduce the learning curve of interacting with a brand new application, thus putting all participants at an equal standing ground on how to operate each of the applications. As such, a short demonstration on all supported features and modalities was conducted with both devices. Participants were asked to use both prototype applications using which modality or set of modalities they felt more comfortable with. Participants used previously created test accounts, which were also pre-configured on the prototype applications, to create a more controlled user environment. In the end of the task, participants were asked the following set of questions to evaluate their subjective opinions about the prototype:

1. Did you enjoy using the application and why?
2. What difficulties did you have using the application and why?
3. Why did you use these interaction modalities?

The following list contains the scripted tasks used for each platform, mobile and desktop. The script for each task was dictated to minimize the temporal effect of reading and interpretation by each participant.

Subjects were also asked to perform the message related tasks (1 through 7) on the mobile device, to better evaluate their interaction with the smaller UI controls and alternative modalities the mobile device offered.

7.2.3 Evaluation Results

This section presents the results of the interaction analysis done over the final user study. Results will be divided into qualitative and quantitative results. Qualitative results will present observations made both by the participant and the researcher as well as an overall

Task	Task Description
1.	Access the Social Media Services area of the application
2.	Edit your user profile on Twitter, by changing your name and current location
3.	Go to the contact management screen
4.	Add *RTPNoticias* as your Twitter contact
5.	View your sent messages
6.	View an image from twitpic.com that is attached to a sent message
7.	Send a *Tweet* (general message) with the following text: "Estou a escrever esta mensagem na Microsoft. Deixa cá ver se é difícil escrever o simbolo do euro: €."
8.	Send a *Tweet* with an attached image
9.	Go to the search area
10.	Search for and view a video of your interest
11.	Go to the audio-visual area and then to photos
12.	Open the first photo album
13.	Access the multi-touch mode and try to control some of the available photos (drag, pinch + zoom, rotate)
14.	Return to the audio-visual area and open the first video album
15.	Add the video on the desktop to the current video album

Table 7.1: Evaluation tasks

result. This result can either represent successful completion of the task at hand, completion of the task with some execution errors noted during the procedure, unsuccessful completion of the task due to the participant exceeding the maximum allowed execution time or *N/A*, which represents that the participant did not execute the task at all. Quantitative results present concrete results such as how long a participant took to complete a task or how many times the researcher had to intervene to help him/her in a particular task. Tasks will be divided by subject, with an overall analysis being presented at the end of the section.

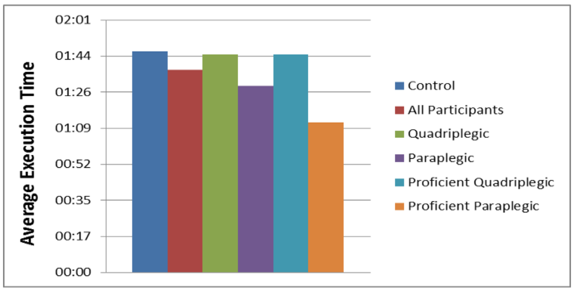
7.2.3.1 Profile Editing

This sub-task comprises of tasks 1. and 2. described in Figure 7.1. The results of this task's execution can be seen in Appendix F.4. Some comments on the performance are presented on the end of this section.

As can be seen in Table F.27, available in Appendix F.4, in this short task there was a slight tendency towards the adoption of a more traditional means of interaction (the keyboard), as well as the device's touch screen, instead of the mouse, a more traditional modality that was also available. Nonetheless, individuals with a higher limitations such as participant 5 chose to use speech, as it allowed them to have faster interaction with the application.

Participant	Result	Time to task completion (minutes:seconds)	Number of aids
Control	Completed successfully	01:46	0
Participant 5	Completed successfully	02:07	0
Participant 7	Completed successfully	01:36	0
Participant 8	Completed successfully	02:04	1
Participant 9	Completed successfully	01:22	0
Participant 10	Completed successfully	00:48	0

Table 7.2: Profile Editing evaluation results



(a) Chart Form

	Average	Standard Deviation	Difference
Control	01:46	-	00:09
All Participants	01:37	00:29	
Quadriplegic	01:45	00:32	00:15
Paraplegic	01:29	00:38	
Proficient Quadriplegic	01:45	00:32	00:33
Proficient Paraplegic	01:12	00:34	

(b) Table Form

Figure 7.1: Profile Editing Participant Execution Times

Time-wise, since this was a short task, the differences between the participants are negligible, however, it's possible to notice that, on average, mobility impaired participants were able to achieve execution times as close as, if not lower than, the control participant. This clearly shows an overall improvement derived from the participant's ability to choose which modality or set of modalities is better suited towards his/her needs as he/she uses the application.

Since this was a simple task, the majority of participants didn't feel any significant difficulties using the application at this time.

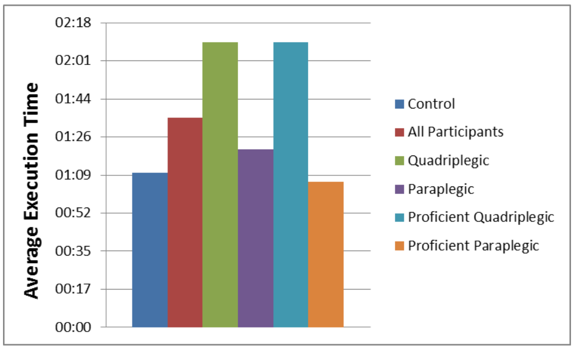
7.2.3.2 Contact Management

This sub-task comprises of tasks 3. and 4. listed in Table 7.1. The results of this task's execution can be seen in Appendix F.4. Some comments on the performance are presented on the end of this section.

As can be seen in Table F.28, available in Appendix F.4, in this task, some of the participants started experimenting with voice command and control (C&C) as well as dictation, however, the majority of participants still adopted the keyboard, be it physical or the on-screen virtual keyboard, or the touch screen. Nonetheless, individuals with higher limitations such as participant 5 continued to use speech, as it allowed them to have faster interaction with the application.

Participant	**Result**	**Time to task completion (minutes:seconds)**	**Number of aids**
Control	Completed successfully	01:10	0
Participant 5	Completed successfully	02:59	1
Participant 7	Completed successfully	01:31	0
Participant 8	Completed successfully	01:50	2
Participant 9	Completed successfully	01:20	1
Participant 10	Completed successfully	00:41	0

Table 7.3: Contact Management evaluation results



(a) Chart Form

	Average	Standard Deviation	Difference
Control	01:10	-	00:25
All Participants	01:35	00:47	
Quadriplegic	02:09	01:10	00:49
Paraplegic	01:21	00:36	
Proficient Quadriplegic	02:09	01:10	01:04
Proficient Paraplegic	01:06	00:35	

(b) Table Form

Figure 7.2: Contact Management Participant Execution Times

Time-wise, it's possible to notice some difference across participants, as can be seen in Figure 7.2. Paraplegic participants were able to perform this task faster than the control, and overall didn't feel many difficulties after an initial adaptation period to the application. Quadriplegic participants who resorted only to speech were somewhat slower than other participants, including the control, as the performance obtained through the use of the dictation engine to enter longer texts was, in this task, somewhat poor. They did, however, manage to complete the task successfully with a slight delay.

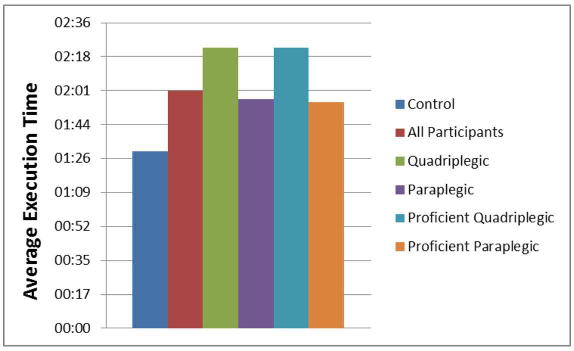
7.2.3.3 Messages

This sub-task comprises of tasks 5. through 8. listed in Table 7.1. The results of this task's execution can be seen in Appendix F.4. Some comments on the performance are presented on the end of this section.

This task was divided into two main types of activities: message viewing and message creation. Message viewing, composed of simple tasks like search for a specific message and its content, was completed by all participants without any major issues, as can be seen Table F.29, available in Appendix F.4. Although time differences are residual, with a maximum difference of about 30 seconds between each group of participants, it should be noted that the control participant resorted mostly to voice control, thus avoiding

Participant	Result	Time to task completion (minutes:seconds)		Number of aids
		Viewing	Creation	
Control	Completed successfully	01:30	04:40	0
Participant 5	Completed successfully	01:46	02:44	0
Participant 7	Completed successfully	01:21	02:30	0
Participant 8	Completed successfully	02:00	04:10	2
Participant 9	Completed successfully	03:00	06:00	3
Participant 10	Completed successfully	02:29	03:00	1

Table 7.4: Message evaluation results

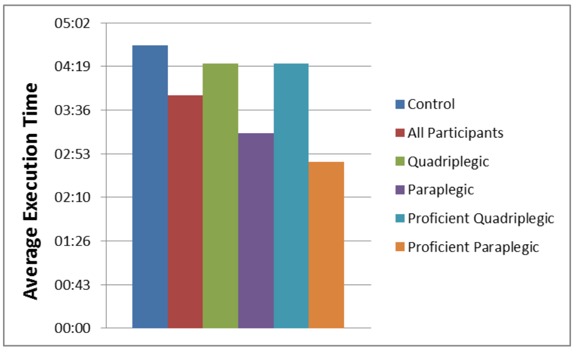


(a) Chart Form

	Average	Standard Deviation	Difference
Control	01:30	-	00:31
All Participants	02:01	00:38	
Quadriplegic	02:23	00:52	00:26
Paraplegic	01:57	00:34	
Proficient Quadriplegic	02:23	00:52	00:28
Proficient Paraplegic	01:55	00:48	

(b) Table Form

Figure 7.3: Message Viewing Participant Execution Times



(a) Chart Form

	Average	Standard Deviation	Difference
Control	04:40	-	00:49
All Participants	03:51	01:21	
Quadriplegic	04:22	02:19	01:09
Paraplegic	03:13	00:51	
Proficient Quadriplegic	04:22	02:19	01:37
Proficient Paraplegic	02:45	00:21	

(b) Table Form

Figure 7.4: Message Sending Participant Execution Times

the main issue participants had with message viewing, which was finding how to trigger a message's context menu, which justifies this difference. These results can be seen in Figure 7.3.

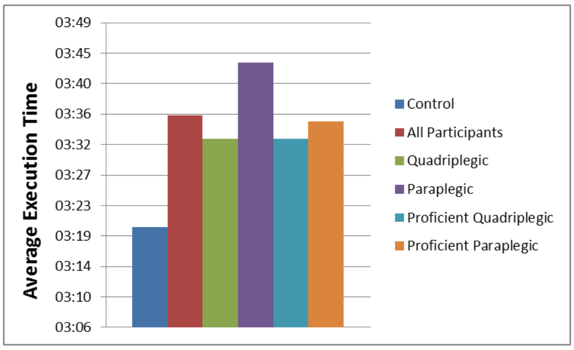
Message creation was, however, where a significant time difference was found. Participants who resorted initially to voice C&C interaction were significantly faster and required little help to perform the tasks. Participants who resorted to touch and keyboard to interact were slightly slower, and participants who switched to other modalities, although taking somewhat more time, required less aids to complete the task. These results can be seen in Figure 7.4.

7.2.3.4 Search

This sub-task comprises of tasks 9. and 10. listed in Table 7.1. The results of this task's execution can be seen in Appendix F.4. Some comments on the performance are presented on the end of this section.

Participant	Result	Time to task completion (minutes:seconds)	Number of aids
Control	Completed successfully	03:20	0
Participant 5	Completed successfully	04:45	1
Participant 7	Completed successfully	03:40	0
Participant 8	Completed successfully	04:00	2
Participant 9	Completed successfully	02:20	1
Participant 10	Completed successfully	03:30	0

Table 7.5: Search evaluation results (part one)



(a) Chart Form

	Average	Standard Deviation	Difference
Control	03:20	-	00:16
All Participants	03:36	00:48	
Quadriplegic	03:33	01:43	00:11
Paraplegic	03:43	00:15	
Proficient Quadriplegic	03:33	01:43	00:03
Proficient Paraplegic	03:35	00:07	

(b) Table Form

Figure 7.5: Search Participant Execution Times

In this task, the multimodal capabilities of this application were truly visible due to the inherent need to use alternative modalities, like speech or the mouse, to more finely control the embedded YouTube video player used in the application. As such, different types of interaction modalities were used, depending on the participants limitations and personal preferences, as would be expected, to complete the task.

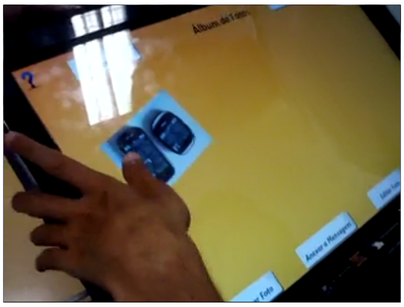
With regards to time, it's not possible to make clear conclusions, as the user experience, and thus the time it took them to search for a subject of their liking, selecting a video and viewing the video took different amounts of time, depending on the subjects own attitude. These results can be seen in Figure 7.5.

7.2.3.5 Audio-Visual

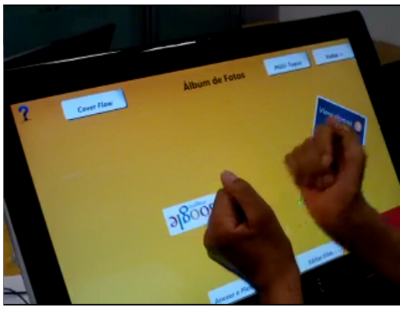
This sub-task comprises of tasks 11. through 15. listed in Table 7.1. The results of this task's execution can be seen in Appendix F.4. Some comments on the performance are presented on the end of this section.

Participant	Result	Time to task completion (minutes:seconds)	Number of aids
Control	Completed successfully	04:36	0
Participant 5	Completed successfully	02:53	1
Participant 7	Completed successfully	04:40	0
Participant 8	Completed successfully	03:00	2
Participant 9	Completed successfully	01:50	1
Participant 10	Completed successfully	06:20	2

Table 7.6: Audio-Visual evaluation results (part one)

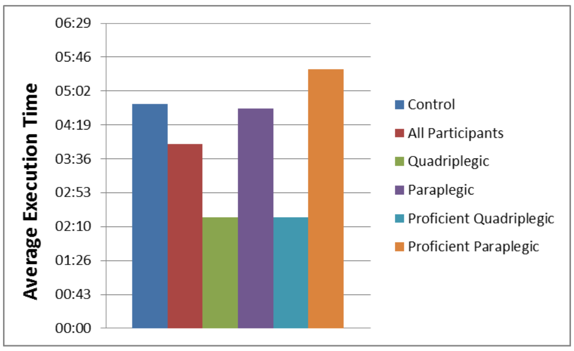


(a) Participant 5



(b) Participant 9

Figure 7.6: Participants using the multi-touch image canvas



(a) Chart Form

	Average	Standard Deviation	Difference
Control	04:46	-	00:51
All Participants	03:55	01:38	
Quadriplegic	02:22	00:45	02:18
Paraplegic	04:40	01:40	
Proficient Quadriplegic	02:22	00:45	03:09
Proficient Paraplegic	05:30	01:11	

(b) Table Form

Figure 7.7: Audio-Visual Participant Execution Times

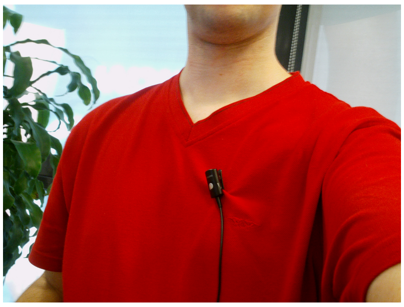
Overall participants had no issues completing this task. Quadriplegic participants were, however, unable to use multi-touch interaction on the prototype, which confirms the hypothesis raised on the second requirements session, as can be seen in Figure 7.6. Participants who resorted to traditional modalities or a set of modalities they had already used with success in previous tasks were able to complete the task faster than those who changed modalities to complete the task, as can be seen in Figure 7.7. None of the participants, however, failed to finish the task, as had happened during the requirements gathering sessions.

7.2.3.6 Messages on a mobile platform

This sub-task comprises of tasks 5. and 7. listed in Table 7.1, executed on the Windows Mobile powered smartphone. The results of this task's execution can be seen in Appendix F.4. Some comments on the performance are presented on the end of this section.

Participant	Result	Time to task completion (minutes:seconds)	Number of aids
Control	Completed successfully	03:43	0
Participant 5	Completed successfully	04:18	1
Participant 7	Completed successfully	03:35	0
Participant 8	Completed successfully	02:56	1
Participant 9	Completed successfully	03:00	1
Participant 10	Completed successfully	02:55	2

Table 7.7: Mobile Messaging evaluation results (part one)

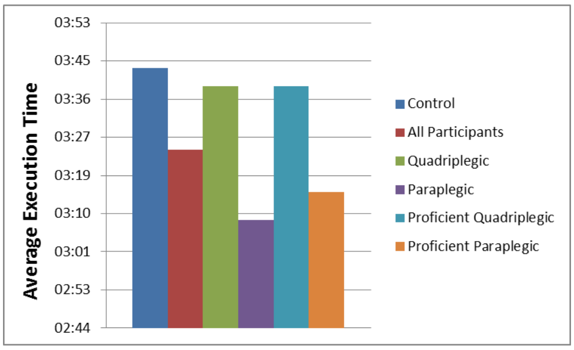


(a) Correct Smartphone microphone position

(b) Participant 5 using the smartphone

Figure 7.8

Interaction on the mobile device was also possible using a variety of modalities, however, it significantly depended on whether the participant was able to properly use the



(a) Chart Form

	Average	Standard Deviation	Difference
Control	03:43	-	00:19
All Participants	03:24	00:33	
Quadriplegic	03:39	00:55	00:30
Paraplegic	03:09	00:23	
Proficient Quadriplegic	03:39	00:55	00:24
Proficient Paraplegic	03:15	00:28	

(b) Table Form

Figure 7.9: Mobile Messaging Participant Execution Times

device's touch screen or not. This can be seen on the interaction time and expressed difficulties of quadriplegic participants who, overall, took longer to complete the task, mainly due to the strength required to operate the device's resistive screen, as the UI had a low learning curve, since it resembled in feature sets and in some cases, UI controls, the desktop's UI. The impact of this issue could be reduced through the support of dictation mode on the device, which was not implemented due to technical limitations. Two other concerns were expressed by the participants and noted while conducting speech command and control trials: The smaller UI components, when compared to the desktop UI, caused some participants to feel the mobile UI to be more difficult to operate. Another key issue when doing speech recognition on the mobile device was the correct positioning of the device's microphone. At first, preliminary internal tests were conducted with resource to the device's own integrated microphone. This proved to be ineffective, as the mic captured, most of the times, an unusually high amount of background noise, thus making it significantly difficult to recognize the captured audio. As such, additional tests were conducted using the device's external lapel microphone. This proved to be more effective, however, to increase capture efficiency, the mic must be attached as depicted in Figure 7.8(a). As such, all tests conducted with the mobile device in voice recognition mode were done using this optimal configuration. It should also be noted that two means of enabling speech were tested during the usability evaluation. At first, the proximity sensor of the device was tested to enable speech recognition for four seconds, which would be signalled to the user through the use of the device's Light Emitting Diode (LED) flash and by vibrating the device for a few milliseconds. This proved to be cumbersome to the participants, especially to quadriplegic users, as it would inadvertently trigger voice recognition whenever these users were trying to adjust their grip on the device. As such, a secondary method was evaluated, which proved significantly better, especially with quadriplegic participants. Users would have to toggle speech recognition through use of one of the device's hardware buttons. Users would be notified of speech recognition status in the same way as with the previous method. Participants felt this method to be slightly better, however, would prefer to engage in a similar fashion to the desktop speech recognition, by simply speaking to the device.

7.2.4 Results Analysis

At the end of each session, participants were asked their overall opinion on the application and modalities.

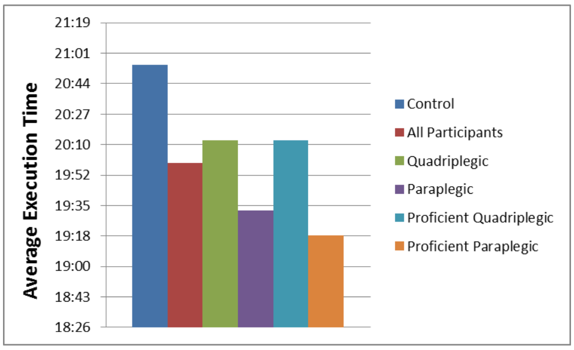
Participant 5, due to his high degree of motor-impairment, was only able to use speech interaction on the desktop device. As such, participant found that voice C&C worked very well, overall, however, dictation support still needs to improve in order to be usable in production environments, as it was slow to react and produced a high error rate. Participant added that dictation mode would be easier to use in opt-out mode, as it accounts for a more natural interaction. Although not able to adequately use touch interaction, the keyboard or the mouse, he found that the existence of these alternative modalities is a must for mobility impaired individuals, especially in scenarios where privacy is needed or where in noisy environments, where speech interaction will not work as well, if not at all. The participant added that although he enjoyed the offered modalities, he is currently more productive with his eye-gaze system. The participant also noted that in situations when he is unable to move at all, speech interaction would be very valuable. The participant finalized by saying that this type of generic modality supporting applications, due to the low level of configuration required to operate, would be ideal to him, especially since it would save him a lot of time when travelling, as his current eye-gaze system requires specific adjustments and calibration to properly operate. With regards to the mobile prototype, participant was very interested in using the application on a day to day basis, as he's required to be mobile most of his day, and bringing his current notebook computer everywhere is not always an option. With regards to the UI itself, the participant had no major issues using both the desktop and mobile UIs, adding however, that desktop UIs would have to fully support either speech or gaze-based interaction for him to be able to use these at all. The participant was also able to find all components in the UI without any major issues.

Participant 7 overall didn't have any significant issues interacting with either the mobile or desktop prototype. He found voice C&C to work with relative ease, although noted he preferred to use touch interaction and keyboard, since he's more used to these modalities, and also because of his voice projection issues. With regards to dictation, the participant also found that it worked better in some situations than in others, and that opt-out dictation would be preferable, as it offers a more natural means of interaction. The participant also found that the availability of different kinds of modalities was positive while interacting with the application, as it offered him the possibility to interact with application as he would find easier, depending on the context. Regarding the mobile prototype application, the participant found the application overall easy to use, however, found that it had a steeper learning curve than the desktop prototype, mainly due to some of the UI components being contained inside nested menus. The participant also found that the Push-To-Talk (PTT) approach broke the interaction flow, and as such, would have enjoyed to use speech interaction in continuous recognition, as what had happened with the desktop prototype. Due to proficiency with other SMSs, like Facebook, this participant didn't have any significant issues using this UI.

Participant 8 overall had some minor issues dealing with the prototype application, however, felt it was significantly easier to use than her current day-to-day applications, noting that she would use it instead to perform some of her daily communication tasks. Participant added that she mostly resorted to the keyboard, be it virtual or physical, and to touch, as these were the modalities that felt more natural to her. She noted that speech wasn't used since she felt it wasn't too effective with her voice's low volume. Regarding the mobile prototype, subject had no major issues dealing with the UI or modalities, however, felt that the device's resistive screen required too much strength to operate. Although not as proficient with SMSs and computers as other participants, participant 8 was able to use the UI with only some minor issues, especially with regards to the search and contact management interfaces. After some trial and error and changing interaction modalities, participant was able to complete the proposed tasks.

Participant 9 noted that, overall, he preferred to interact with touch, be it to select controls or to type, as he finds speech interaction to be somewhat imprecise in certain situations, and found touch to be easier to use than the conventional mouse and keyboard combination, which requires him to operate the peripherals with two hands, as opposed to only one with touch. He added, however, that given some time, he would probably get used to using speech interaction. He believes, however, that the concept of multimodality, is very useful as a means of redundant input and output. The participant found the UI itself very easy to use, especially the desktop version, having only some minor issues with some the contact management and message viewing UIs, resorting to voice to overcome these difficulties. With regards to voice interaction, he found C&C to work better than he expected, with dictation feeling imprecise in certain situations. He felt, as with most participants, that the mobile device's screen required too much pressure to react, and as such, would like it to offer a pressure sensitivity adjustment.

Participant 10 noted that he preferred to use touch and keyboard, as opposed to other modalities, as he found these to be slightly more effective than other offered modalities, like speech interaction. He added that this was most noticeable while testing dictation, as he found that typing on the keyboard was much faster to him. He added that he also found the on-screen keyboard was slower to him than the physical keyboard. Participant believes, however, that the seamless availability of different interaction modalities would improve his daily activities, allowing him to perform multiple tasks simultaneously, such as reading the latest posts by his social network friends while getting ready for school in the morning. Regarding the mobile device, he found the device's modalities and UI overall easy to use, however, believes that voice C&C on this device would require him some getting used to. He added that the smaller UI controls on the device also gave him a clear impression that the UI was slightly more difficult to use than the desktop version.



(a) Chart Form

	Average	Standard Deviation	Difference
Control	20:55	-	00:56
All Participants	19:59	01:05	
Quadriplegic	20:12	01:53	00:40
Paraplegic	19:32	00:35	
Proficient Quadriplegic	20:12	01:53	00:54
Proficient Paraplegic	19:18	00:35	

(b) Table Form

Figure 7.10: Global Participant Execution Times

Although there were slight temporal differences in each individual task, depending on several factors like chosen interaction modalities, task error rate, or UI experimentation time, a clear pattern can be extracted from Figure 7.10, which is that, overall, mobility impaired individuals were slightly faster executing the proposed tasks using this multi-modal approach. Although further experimentation with a larger sample group would be required to reach conclusive results, it's possible to extrapolate from these results and the subjective opinions expressed by the participants that this multi-modal approach does indeed improve mobility impaired individuals' experience with SMSs, regardless of the type or level of impairment, as the application can be adapted to the user's needs, and not the other way around.

7.3 Summary

An overall improvement in the users' experience was noticeable by the presented results. When compared to the results obtained in the requirements gathering sessions presented in Chapter 3. Obtained error rates lowered substantially, with participants being able to successfully complete all proposed tasks, with execution times lower than the control participant's.

Participants overall enjoyed the application, finding it easy to use, with a low learning curve and clear, large and easy to use UI controls. Overall participants preferred to use modalities they were more used to such the keyboard, be it the virtual on-screen variant or the physical keyboard. Participants felt, however, that touch interaction was more natural, in detriment of the mouse, a tendency that was verified in all participants, as the mouse wasn't used at all during the proposed tasks. With regard to speech interaction, several factors influenced the overall experience, such as the participant's tone, volume, cadence, among other factors. Voice interaction in C&C mode proved very effective should the participant be able to project his or her voice with enough volume to be captured by the device's microphone. Depending on the task, dictation mode either worked as expected, or didn't produce adequate results at all, a side-effect that was expected, as its model is still very preliminary. Participants, however, felt that the combination of different input and output modalities can significantly improve their daily interaction with SMSs, attributing advantages to this interaction approach such as the ability to change to more suited modalities based on privacy needs, to perform tasks that they don't know exactly how to perform with a specific modality, to allow them to multi-task on their daily lives, or to improve mobility, be it to interact with a mobile device while driving or while traveling. Participants who use custom interaction devices, such as Participant 5, felt that using multimodal applications allow them to interact with peripherals they're most used to, and at the same time, allow them to interact with the applications through different modalities that require less configuration, or none at all, should the need arise, in a seamless, transparent way.

With regards to the particular hardware used in these evaluation sessions, participants felt that the desktop computer operated better than the mobile device, especially with regards to the voice and touch interaction capabilities. Further technical improvements with regards to the way the voice stream is transmitted to the backend system, as well as using a capacitive touch screen smartphone would be some changes that could improve the participants' user experience while interacting with these devices.

Chapter 8

Conclusions and Future Work

Although social media services have been around for more than a decade, and many advanced have been made to make these more accessible, especially web-based services, most desktop and mobile social media applications still can't be fully used by mobility impaired citizens.

Much work has also been done over the past 30 years in state-of-the-art multimodal interaction, however, as of the writing of this work, there is still a lack of studiers portraying the effects of multimodal interaction to social media services, with respect to mobility impaired individuals. This dissertation thus focused on evaluating these effects, and if in fact, it is possible to improve mobility impaired individuals' user experience with these services through the use of this interaction paradigm.

An initial generic short study was thus conducted to evaluate mobility impaired individuals' technology use patterns, ICT proficiency and main ICT interaction difficulties. This study was conducted in a group session, with five volunteer mobility impaired participants from Associação Salvador. These participants were asked to answer the questionnaire presented in Appendix A.2.

Following this study, a more thorough study was conducted with each individual participant of an extended group of ten volunteer mobility impaired participants, also from Associação Salvador, with the intent of gathering user and functional requirements in the area of Social Media Services, as well as gathering in-depth data regarding mobility impaired individuals' interaction limitation with a variety of input and output modalities. Participants were asked to perform a series of tasks to assess their usage of modalities and associated hardware, as well as interaction with SMSs such as Twitter, Facebook or YouTube.

With this valuable feedback, it was possible to elaborate the system's architecture, distributed over several platforms, as described in Chapter 5, which led to the development of an SDK geared towards the development of multimodal applications that allow interaction with several SMSs, and two proof-of-concept applications, one desktop based and one mobile based.

Finally, both proof-of-concept applications were used for a third study, conducted with five of the previous volunteer participants, to evaluate the usability of these applications with mobility impaired individuals.

A paper with the results of the two requirements gathering sessions was also elaborated, submitted and accepted to the Social Mobile Web 2010 workshop [Wor10a, dNTGPdSP]. This paper was also elaborated in conjunction with the author of [dNTGP], and as such, combines the results of both requirements gathering sessions.

8.1 Conclusions

The results of the evaluation session conducted with a sample of five mobility impaired participants from Associação Salvador confirm the initial hypothesis that multimodal User Interfaces (UI) can indeed improve the overall user experience with Social Media Service applications by reducing the negative impact the smaller UI controls can have on the interaction by mobility impaired individuals with these kinds of applications, as well as the learning curve of the application, by allowing users to interact with modalities that they feel are more natural. This was verified with respect to touch, a modality that all participants found was more natural to use to perform pointer interaction, as opposed to the mouse, a peripheral that they rarely used. It was thus possible to verify a positive opinion with regard to this interaction paradigm, as the participants were able to choose their preferred modalities to interact with the prototype application. It was also demonstrated that, as the initial sessions pointed to, that multi-touch interaction was very hard to use, and in some cases, impossible to use, by quadriplegic individuals, due to their higher level of motor impairments.

With respect to voice interaction, the final prototype evaluation also confirmed what was hypothesized with the preliminary hardware tests conducted during the second round of sessions, which was that voice command and control would work with very high levels of accurate recognition, and that dictation support (also known as free text input) would produce overall poor results, derived from the yet early language model in use. Surprisingly, however, under certain situations, such as name dictation and shorter sentence dictation, this model worked really well, producing good results. The poor results, however, somewhat conditioned user adoption of voice as a main interaction modality, resorting to the devices' keyboards, on-screen or physical, as well as touch.

Surprisingly, however, quadriplegic participants didn't have many difficulties using the mobile device's on-screen keyboard as would be expected, although overall, felt that dictation support would help them have a better experience with the device, by allowing them to *type* faster on the device.

During the requirements gathering sessions it was also possible to elaborate a list of functional requirements specific to the domain of the prototype application, as well as a list of generic UI development recommendations, presented in Chapter 4 as the application's non-functional requirements. These recommendations range from use of appropriately sized text, icons, avoidance of service specific jargon in applications, as it may confuse users who aren't used to SMSs, and also, scenarios where specific types of modalities, such as touch, 2D gesture or voice are more adequate. These requirements were thus used to guide the development of both the proposed SDK and proof-of-concept software, which were successfully completed, and are deemed fully functional, supporting the proposed features.

8.2 Future Work

This section presents some directions for future work based on this dissertation work and its content, divided by subject, accordingly.

8.2.1 Extended Hardware Evaluation

The evaluation on the mobile device allowed to conclude that participants, be they quadriplegic or paraplegic, found the device's resistive screen to be somewhat more difficult to use than the desktop computer's capacitive touch screen, an issue that influenced their opinion of touch interaction on the mobile device, and thus, needs to be further studied, to evaluate if, in fact, different kinds of hardware, be they with different screen sizes, Software Input Panel (SIP) types and touch screen types, can influence the participants interaction and overall application opinion.

8.2.2 Enhanced Speech Models

As noted by the participants, dictation support was still offering poor performance in certain scenarios. As such, future work should also attempt to use improved dictation models and evaluate if usage under mobile and desktop scenarios can indeed provide for better user experience, especially with quadriplegic individuals.

8.2.3 Prototype Improvements

Several technical limitations were noted during testing and evaluation of the prototype, and as such, future work should also focus on enhancing these issues to provide a better user experience to the user. As such, these include, but are not limited to the following:

8.2.3.1 Platform Improvements

- Add support for sequential modality processing through the use of an enhanced fusion and fission combined engine.
- Upgrade the prototype desktop application to support .Net 4.0 Framework, thus improving multi-touch support through usage of newer managed C# APIs.
- Upgrade the prototype mobile application to a newer platform like the .Net 4.0 Framework and Windows Phone 7 to evaluate if newer mobile UI development paradigms can enhance mobility impaired individuals' user experience.
- Improve voice interaction support on the mobile platform by developing voice streaming capabilities on the mobile platform, thus removing the need for one of the main complaints of participants, push-to-talk interaction.
- Add dictation support to mobile, which was purposely not implemented due to technical limitations with speech broadcast to the backend recognition service.
- Improve prototype scalability, by allowing the same backend server to support connections from multiple devices, thus maintaining an internal device specific state.

8.2.3.2 Service Improvements

Besides generic prototype improvements, the following list of service specific improvements should also be taken into account on future work.

- Add support for Facebook and Flickr and evaluate user interaction with these services.
- Evaluate user interaction with music services such as on-line radios and Last.fm.
- Evaluate the need for, and benefits of supporting multi-touch in video playback.

8.2.4 Extended User Evaluation

Future work on this subject should also study these hypothesis on an extended audience, as additional insights can be obtained under those conditions. It should also be of interest to study user interaction with this kind of prototype applications under real-life scenarios, by allowing participants to use the applications while working, at home, or in other situations. These extended evaluations should provide for additional valuable data towards the advancement of mobility impaired individuals' interaction with Social Media Services.

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Appendix A

Questionnaire

A.1 Requirements Analysis Questionnaires

Due to the nature of the requirements' analysis process used, namely, User-Centred Design, some studies were conducted during the elaboration of this dissertation, to gather relevant information from the a group of users with mobility impairments. A table is now presented with data regarding the sample users from Associação Salvador, who collaborated throughout this study:

Name	**Sex**	**Age**	**Professional Area**	**Disability**
Participant 1	Female	25	Life Sciences Technician	Quadriplegic
Participant 2	Male	43	Computer Technician	Quadriplegic
Participant 3	Male	47	Book Keeper	Paraplegic
Participant 4	Female	26	Unemployed (Social Psychologist)	Paraplegic
Participant 5	Male	28	General Manager	Quadriplegic
Participant 6	Male	37	Unemployed	Quadriplegic
Participant 7	Male	36	Computer Technician	Paraplegic
Participant 8	Female	54	Technical Assistant	Paraplegic
Participant 9	Male	41	Computer Engineer	Quadriplegic
Participant 10	Male	19	Student	Paraplegic
Participant 11	Male	40	Enologist	Quadriplegic

Table A.1: Study Participant

A.2 Initial Requirements Analysis Questionnaire

This initial questionnaire was conducted in an interactive environment, over the Microsoft Live Meeting platform, in January 19th 2010, between 15:30 and 17:20. The main focus of this user study was to determine technology usage by these individuals, as well as main usage difficulties and how would they improve the usability of applications. The questionnaire and responses will be presented in this section.

A.2.1 Questionnaire

1. On average, how would you describe your computer usage habits:

   1 - Never used
   2 - Sporadic usage (less than once a week)
   3 - Weekly usage (at least once a week)
   4 - Daily usage (less than five hours a day)
   5 - Intense usage (more than five hours a day)

Name	Response
Participant 1	5
Participant 2	5
Participant 3	5
Participant 4	5
Participant 5	5

2. On average, how would you describe your smartphone usage habits:

   1 - Never used
   2 - Sporadic usage (less than once a week)
   3 - Weekly usage (at least once a week)
   4 - Daily usage (less than five hours a day)
   5 - Intense usage (more than five hours a day)

Name	Response
Participant 1	1
Participant 2	1
Participant 3	1
Participant 4	1
Participant 5	1

3. On average, how would you describe your cellphone usage habits:

   1 - Never used
   2 - Sporadic usage (less than once a week)

3 - Weekly usage (at least once a week)
4 - Daily usage (less than five hours a day)
5 - Intense usage (more than five hours a day)

Name	**Response**
Participant 1	4
Participant 2	4
Participant 3	4
Participant 4	4
Participant 5	5

4. How would you rank your level of easiness of use of a computer:

1 - Very Low
2 - Low
3 - Medium
4 - High
5 - Very High

Name	**Response**
Participant 1	4
Participant 2	4
Participant 3	5
Participant 4	4
Participant 5	2

Participant 2 noted that at first he had some difficulties writing on the keyboard, but now uses pens to type on the keyboard, as well as the mouse.

Participant 3 mentioned that, although he is used to using computers in his line of work, thus having a high level of easiness of use, he still considers that there is room for improvement.

Participants 1 and 4 also noted that their interaction with computers could also stand for some improvement.

Participant 5, since he's a quadriplegic, has a lot of difficulties using these devices, and thus considers that there is a lot of room for improvement.

5. How would you rank your level of easiness of use of a cellphone:

1 - Very Low
2 - Low
3 - Medium
4 - High

5 - Very High

Name	Response
Participant 1	3
Participant 2	3
Participant 3	5
Participant 4	2
Participant 5	2

6. Do you use the computer for entertainment, work, or both?

Participant 1 said that since she works from home, she mostly uses the computer for work.

Participant 2 replied that he uses the computer essentially for work, but at home he sometimes uses it for entertainment purposes.

Participant 3 answered that more than 90% of his time spent in front of a computer is for work purposes, but he still uses it a bit for entertainment, at home.

Participant 4 answered that, since she's unemployed, most of her usage is personal.

Participant 5 replied that he uses it mostly for work related activities.

7. Do you use the cellphone for entertainment, work, or both?

Participant 1 said that since she works from home, she mostly uses her cellphone for work activities.

Participant 2 replied that he uses the cellphone exclusively for work.

Participant 3 answered that more than 90% of his time spent with a cellphone is for work purposes.

Participant 4 answered that, since she's unemployed, most of her usage is personal.

Participant 5 replied that he uses it mostly for work related activities.

8. What do you usually do on your computer/cellphone?

Participant 1 said that she uses her computer for web browsing, Instant Messaging, e-mail, social network access, document elaboration in Word and presentation creation in PowerPoint. She doesn't use her computer for audio or video-conferencing, as well as for gaming.

Participant 2 replied that he browses the web, uses management applications, SAP in his work place, e-mail, some chatting at night. He also likes to watch movies and photos. Participant 2 also mentioned that he does not do audio or video conferencing.

Participant 3 uses these devices to read daily sports and economy on-line newspapers and to e-mail. He mentioned that he does not know, nor have the time to play games.

Participant 4 uses her computer for e-mail, Instant Messaging, audio and video-conferencing, as well as for photo viewing, document writing in Word and presentation elaboration in PowerPoint. She also mentioned that she doesn't play games on her computer.

Participant 5 mentioned that he uses his computer for e-mail, to elaborate spreadsheets in Excel and presentations in PowerPoint, as well as on-line newspaper reading and researching. He also uses his computer for a bit of casual gaming, and once or twice a month for video-conferencing with friends and for work related situations.

9. What are your main difficulties while using a computer?

Participant 1 also noted that her difficulties are focused on keyboard writing, due to some issues with her hands. She also suggested adopting auto-completion writing or voice recognition as additional ways of interfacing with the computer.

Participant 2 answered key combinations, such as ctrl+alt+delete, usb thumbdrive removal and cd/dvd insertion and removal are his main difficulties.

Participant 3 mentioned that his main difficulty is having to change his glasses to ones designed specifically for computer usage.

Participant 4 reported that her main difficulties are with keyboard and mouse usage, suggesting the adoption of auto-completion writing or voice recognition technologies as keyboard aids and alternative ways of hands-free mouse control.

Participant 5 replied that he has difficulties writing for long periods of time (more than 5 hours) on the keyboard, suggesting the adoption of features such as auto-completion or most frequently typed words. Some of his other issues regard high movement effort that he has to sustain in order to do simple tasks, as well as dependency on others to perform simple tasks such as putting on eye-glasses designed for gaze control, as well as turning on the computer. He suggested adoption of a multitouch interface as a way to simplify turning on the computer.

10. What are your main difficulties while using a cellphone?

Participant 1 did not reply to this question.

Participant 2 answered that his difficulties are related with small keys on the cellphone, forcing him to use his knuckles to type.

Participant 3 did not have any difficulties with cellphone usage.

Participant 4 also mentioned that her difficulties regard using small keys.

Participant 5 also has issues with small keys on the cellphone, forcing him to use his thumb as a way to write. He mentioned that, due to the position of the power button, it was also very hard for him to turn the cellphone on or off, suggesting adoption of a multitouch way to control this feature.

11. Which interaction modalities have you used to interact with computers and cellphones?

Participants 1 and 4 have also only used keyboard and mouse.

Participant 2 has used keyboard, with and without pens, and the mouse, noting that he is very used to keyboard and mouse interaction.

Participant 3 has only used keyboard and mouse.

Participant 5 has used the keyboard and mouse combination, as well as multitouch screens in Windows 7, noting that gestures such as pinch+zoom weren't very easy for him to used, as he can't move his fingers very easily. He has also used voice recognition software such as Philips' Freespeech and IBM's viavoice, noting that these older systems didn't work very well in open spaces due to the presence of other voices in the environment.

12. If you could use just one modality, which would you choose and why?

Participant 1 would choose voice, due to her finger dexterity limitations.

Participant 2 replied that he would use voice recognition and synthesis, as long as its usage was efficient. When asked if he would use gesture commands, he answered that it wouldn't be adequate for him to use as it requires too much movement.

Participant 3 answered that, out of curiosity, he would like to try voice interaction.

Participant 4 would also like to try voice and maybe gaze interaction.

Participant 5, due to his limitations, answered that voice and gaze interaction would be the more adequate interfaces.

13. Have you ever used hardware or software targeted towards mobility impaired users?

Participants 1, 3 and 4 haven't used any of the aforementioned hardware or software.

Participant 2 has only used pens.

Participant 5 uses gaze control glasses and his wheelchair's joystick, as an alternative way to control his mouse's pointer, noting that he uses these devices since he can produce more accurate movements with his neck, than with his hands.

(a) What was good about your interaction with them?

Participant 2 mentioned that the pens he uses can be found almost anywhere, thus having a low price point, and that it's also very easy to find alternatives to them.

Participant 5 replied that without those devices, he couldn't use any computer.

(b) What was bad about your interaction with them?

Participant 5 replied that the particular eye-glasses gaze interface he uses isn't very easy to deploy on other computers, due to requiring specific wiring and software, thus forcing him to always bring his own computer with him, whenever needed.

14. Have you ever heard of social networks on the Internet?

Name	**Response**
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 4	Yes
Participant 5	Yes

15. Have you ever heard of content sharing services (i.e.: photo sharing, video sharing) or message sharing services (i.e.: forums)?

Name	**Response**
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 4	Yes
Participant 5	Yes

16. If you have heard of any of those

(a) Which social networks and services do you know of?

Name	Response
Participant 1	Facebook, MSN Messenger
Participant 2	Facebook, Twitter, Hi5, MSN Messenger
Participant 3	Facebook, Twitter, Hi5
Participant 4	Facebook, Gmail, MSN Messenger
Participant 5	Facebook, Twitter, Forums

(b) What kind of usage do you foresee being given to these services?

Participant 1 believes that these services can help her share photos, messages and chat with friends and family, as well as helping her find information regarding people she hasn't been in touch with for some time.

Participant 2 told that with services such as Facebook he should be able to contact people who he hasn't seen for some time, thus maintaining social connections. He also believes that these services could easily be used as a way to interconnect, on a professional level, with work colleagues.

Participant 3 doesn't think that social networks have any usage in his current day-to-day activities.

Participant 4 believes that these services can help her exchange messages with friends and family, thus helping her keep in touch with them.

Participant 5 believes that social network services can also help him contact friends he hasn't seen for some time, as well as meeting new people. He believes that social networks have tremendous power, especially through possibilities of information sharing.

17. Have you ever used social networks on the Internet?

Name	Response
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 4	Yes
Participant 5	Yes

18. Have you ever used content sharing services (i.e.: photo sharing, video sharing) or message sharing services (i.e.: forums)?

Name	Response
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 4	Yes
Participant 5	Yes

19. How frequently do you use these services?

    1 - Never used
    2 - Sporadic usage (less than once a week)
    3 - Weekly usage (at least once a week)
    4 - Daily usage (less than five hours a day)
    5 - Intense usage (more than five hours a day)

Name	Response
Participant 1	4
Participant 2	4
Participant 3	2
Participant 4	4
Participant 5	4

Participant 2 noted that his daily usage is more due to MSN Messenger usage.

Participant 4 also added that her daily usage is also mainly due to MSN Messenger and Gmail chat.

Participant 5 added that he uses these services for about thirty minutes every day.

20. If you have used any of those

    (a) Which social networks and services have you used?

Name	Response
Participant 1	Facebook, MSN Messenger
Participant 2	Facebook, MSN Messenger
Participant 3	Facebook
Participant 4	Facebook, Gmail, MSN Messenger
Participant 5	Facebook, Forums

Participant 4 noted that, although she uses Facebook, most of her time spent with these services is in Gmail and MSN Messenger.

(b) What have you used these services for?

Participant 1 uses these services to chat with friends and exchange photos.

Participant 2 replied that he uses these services for communication purposes, especially MSN Messenger.

Participant 3, although he doesn't use these services a lot, uses Facebook as a way to keep up-to-date with news from Associção Salvador.

Participant 4 said that she uses these services to keep in touch and up-to-date with friends, as well as to watch videos.

Participant 5 uses these services as a way to re-connect with friends he hasn't seen for quite some time, to meet new people, to share information with friends and family, and in a professional environment, to share information.

(c) What difficulties do you have while using these services?

Participants 1 and 4 noted that their main difficulties with these services is the time it takes to type something with the keyboard, suggesting the adoption of text auto-completion and voice interaction.

Participant 2 mentioned that overall his difficulties lie with writing speed and sometimes switching letters. In MSN Messenger he noted that it can be very tiring to write, suggesting that auto-completion could help him better use that service. He also noted that Facebook usage can be overwhelmingly complicated due to its many features.

Participant 3 pointed that his writing difficulties limit his adoption of these services.

Participant 5 noted that his main difficulties relate to those with computer systems, severely limiting his communication with people on-line. He wished he could further communicate with more people on a daily basis, however feels that his current methods are too tiring.

21. How many people do you keep in touch with?

Name	**Response**
Participant 1	A few people
Participant 2	Tens of people
Participant 3	N/R [1]
Participant 4	N/R
Participant 5	Hundreds of people

22. Who do you believe ICTs help keep in touch with?

Participant 1 mentioned that she uses ICTs to keep in touch with family, friends and acquaintances.

Participant 2 answered family, friends and work colleagues.

Participant 3 believes ICTs help him communicate with whomever should be needed at a given time.

Participant 4 mentioned that she uses ICTs to keep in touch with friends.

Participant 5 said that he uses ICTs to keep in touch with friends who live outside Portugal, as well as with people who can't easily move, especially in his work area, allowing him to easily exchange information with paraplegic and quadriplegic people who live in isolated villages.

23. Where do you currently store your digital media?

Participant 1 stores her media in an external hard drive.

Participant 2 stores his media in his digital camera and in an external hard drive. He also noted that he's not much into sharing media.

Participants 3 and 4 mainly use their computers as a storage medium.

Participant 5 uses an external hard drive, while also storing photos, music and videos in his computer.

24. Would you prefer to use ubiquitous ICTs or localized ICT devices?

Participants 1 and 2 believe that ubiquitous ICTs, available in small surfaces (mobile phones), medium sized (tablet computer) and large sized (home entertainment system) would greatly increase his usage of these technologies.

Participant 3 prefers to use portable ICTs such as a cellphone and notebook computer.

Participant 4 believes that the more interaction possibilities, the better.

Participant 5 would also prefer to have access to ICTs all-over his house. Although he already has some controls on his wheelchair, which allow him to control some home entertainment devices, as well as opening and closing doors, he believes that voice interaction can allow him to do more in his home, such as making a call while in bed, or even increase his autonomy, by allowing him to stay home alone, without fear of becoming deprived of communication with the outside world, should something happen.

A.3 Second Requirements Analysis Session

Ten in-depth and personal sessions were conducted between the days of 17 and 19 of March 2010, in Lisbon, Oeiras and Sintra, as well as in Matosinhos (OPorto) on March 22nd 2010. These sessions focused on testing user interaction in the fields of social network services (SNSs) and social media services (SMSs), allowing the detection of usage issues by mobility impaired users, as well as how alternative I/O modalities, such as speech and touch, would influence their user experience. Some hardware tests were also conducted in the fields of European Portuguese speech recognition and synthesis, touch and digital stylus interaction with a Windows powered tablet PC and a Windows Mobile smartphone. The initial questionnaire, conducted with the smaller sample audience in January, was also used with newer audience members who didn't take part in the previous session. A newer, more specific questionnaire was also used to gather user interest in specific SNS's and SMS's. The questionnaires and responses will be presented in the following two sections.

A.3.1 Profile Questionnaire

1. On average, how would you describe your computer usage habits:

   1 - Never used

   2 - Sporadic usage (less than once a week)

   3 - Weekly usage (at least once a week)

   4 - Daily usage (less than five hours a day)

   5 - Intense usage (more than five hours a day)

Name	Response
Participant 6	3
Participant 7	5
Participant 8	5
Participant 9	5
Participant 10	4
Participant 11	5

2. On average, how would you describe your smartphone usage habits:

   1 - Never used

   2 - Sporadic usage (less than once a week)

   3 - Weekly usage (at least once a week)

   4 - Daily usage (less than five hours a day)

   5 - Intense usage (more than five hours a day)

Name	Response
Participant 6	1
Participant 7	5
Participant 8	1
Participant 9	1
Participant 10	1
Participant 11	4

3. On average, how would you describe your cellphone usage habits:

   1 - Never used
   2 - Sporadic usage (less than once a week)
   3 - Weekly usage (at least once a week)
   4 - Daily usage (less than five hours a day)
   5 - Intense usage (more than five hours a day)

Name	Response
Participant 6	5
Participant 7	5
Participant 8	4
Participant 9	4
Participant 10	5
Participant 11	4

4. How would you rank your level of easiness of use of a computer:

   1 - Very Low
   2 - Low
   3 - Medium
   4 - High
   5 - Very High

Name	Response
Participant 6	3
Participant 7	5
Participant 8	3
Participant 9	5
Participant 10	3
Participant 11	4

5. How would you rank your level of easiness of use of a cellphone:

1 - Very Low
2 - Low
3 - Medium
4 - High
5 - Very High

Name	**Response**
Participant 6	3
Participant 7	5
Participant 8	3
Participant 9	5
Participant 10	4
Participant 11	4

A.3.2 Requirements Questionnaire

1. How difficult is it for you to use a touch screen on a computer, according to the following scale:

   1 - Impossible

   2 - Very Hard

   3 - Hard

   4 - Medium

   5 - Easy

   6 - Very Easy

Name	Response
Participant 1	2
Participant 2	5
Participant 3	N/R
Participant 5	3
Participant 6	5
Participant 7	6
Participant 8	4
Participant 9	4
Participant 10	4
Participant 11	3

   Participant 2 noted that it's easier for him to use a touch interface horizontally, rather than vertically.

   Participant 5 has already used touch interaction in a notebook device and found that it's hard to use due to his degree of quadriplegia.

2. How difficult is it for you to use a voice as an interaction modality, according to the following scale:

   1 - Impossible

   2 - Very Hard

   3 - Hard

   4 - Medium

   5 - Easy

   6 - Very Easy

Name	Response
Participant 1	6
Participant 2	6
Participant 3	N/R
Participant 5	4
Participant 6	5
Participant 7	5
Participant 8	5
Participant 9	5
Participant 10	6
Participant 11	5

Participant 5 believes that voice interaction is easier to use, however, experience with previous systems has shown him that, in open space environments, noise substantially reduces the effectiveness of the system.

Participant 7 noted that voice interaction can be problematic over longer periods of time due to some speaking issues he has.

3. How difficult is it for you to use a touch screen on a smartphone, according to the following scale:

   1 - Impossible
   2 - Very Hard
   3 - Hard
   4 - Medium
   5 - Easy
   6 - Very Easy

Name	Response
Participant 1	1
Participant 2	4
Participant 3	N/R
Participant 5	3
Participant 6	5
Participant 7	6
Participant 8	5
Participant 9	5
Participant 10	5
Participant 11	3

Participant 5 believes that his interaction with smartphones would be easier if the interface had bigger icons, since he cannot move his fingers. Usage of mobile devices also requires the device to be standing on a stable surface.

Participant 6 needs the smartphone to be standing on a stable surface to use it properly.

4. How difficult is it for you to use a smartphone accelerometer, according to the following scale:

    1 - Impossible
    2 - Very Hard
    3 - Hard
    4 - Medium
    5 - Easy
    6 - Very Easy

Name	**Response**
Participant 1	1
Participant 2	3
Participant 3	N/R
Participant 5	1
Participant 6	5
Participant 7	6
Participant 8	3
Participant 9	3
Participant 10	5
Participant 11	4

Participant 10 considered that simple accelerometer control, such as with a dice launch game was easy to use, while more complex activities such as controlling a car in a video game was harder.

5. Considering the interaction modalities you just used, which ones did you prefer?

Name	**Response**
Participant 1	Speech interaction
Participant 2	Speech interaction
Participant 3	N/R
Participant 5	N/R
Participant 6	Touch screen (digital stylus input)
Participant 7	Smartphone touch screen, keyboard, mouse
Participant 8	Speech interaction
Participant 9	Smartphone touch screen
Participant 10	Speech interaction
Participant 11	Speech interaction, accelerometer interaction

Participant 11 noted that he was surprised how easy it was for him to use the smartphone's accelerometer to control some games, as well as how easy it was to use speech, namely in European Portuguese.

6. Considering the interaction modalities you just used, which ones did you dislike?

Name	Response
Participant 1	Touch on the smartphone and tablet writing
Participant 2	Smartphone accelerometer interaction
Participant 3	N/R
Participant 5	N/R
Participant 6	Keyboard
Participant 7	Speech interaction
Participant 8	N/R
Participant 9	Speech interaction and tablet writing
Participant 10	Tablet writing
Participant 11	Tablet writing

Participant 6 believes that voice interaction is strange to use, and as such wouldn't like to use it on a daily basis.

Participant 7 added that he doesn't think voice interaction is very practical, taking into account how evolved speech recognition technology is today.

Participant 11 noted that, for him, writing on a tablet with a digital stylus isn't very practical, as he can write faster with the keyboard.

7. How would alternate interaction modalities such as voice, touch screens or gestures improve your daily usage of ICT's?

Participant 1 replied that voice recognition would greatly improve her daily interaction with computers, especially for work related tasks, in which, European Portuguese dictation support would help in text composition. Participant 1 also believes that voice command interaction would greatly improve her interaction with social network and social media services, mainly in those where the amount of possible user actions is overwhelming.

Due to his job requirements, Participant 2 is already used to typing on a keyboard. He believes, however, that voice recognition in command and control mode would him interacting with complex environments.

Participant 3 didn't reply to this question.

Participant 5 believes that voice recognition would greatly improve his text writing and computer interaction experience, especially when he's at home writing short texts or larger texts at the office, later in the day.

Participant 6 added that key combinations are hard for him to enter, believing that a virtual keyboard with special characters would simplify his interaction.

Participant 7 believes that if speech recognition was more evolved that it is today, it could help him in his daily tasks, especially for authentication and dictation purposes.

Participant 8 believes that voice interaction, especially while in dictation mode, would help her a lot during her daily tasks.

Participant 9 believes that if speech recognition was more evolved that it is today, it could help him in his daily tasks.

Participant 10 believes that these alternative modalities won't significantly influence his daily activities.

Participant 11 noted that speech interaction, especially dictation mode, would substantially increase his interaction with the computer. He noted that he eagerly awaits for full dictation support in European Portuguese, estimating that he would use dictation in 90% of his daily computer interactions and voice command and control in 10% of his interactions.

8. Have you ever heard of social networks on the Internet?

Name	**Response**
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 5	Yes
Participant 6	Yes
Participant 7	Yes
Participant 8	No
Participant 9	Yes
Participant 10	Yes
Participant 11	Yes

9. Have you ever heard of content sharing services (i.e.: photo sharing, video sharing) or message sharing services (i.e.: forums)?

Name	**Response**
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 5	Yes
Participant 6	Yes
Participant 7	Yes
Participant 8	No
Participant 9	Yes
Participant 10	Yes
Participant 11	Yes

10. If you have heard of any of those

    (a) Which social networks do you know of?

Name	Response
Participant 1	Facebook, Twitter, Hi5, LinkedIn
Participant 2	Facebook, Twitter, Hi5
Participant 3	Facebook, Twitter, Hi5
Participant 5	Facebook, Twitter
Participant 6	Facebook
Participant 7	Facebook, Twitter, Hi5, LinkedIn
Participant 8	-
Participant 9	Facebook, Twitter, Hi5, LinkedIn
Participant 10	Facebook, Hi5, Tagged
Participant 11	Facebook, Twitter, Hi5, LinkedIn

(b) Which content sharing services do you know of?

Name	Response
Participant 1	YouTube, MSN Messenger
Participant 2	Flickr, YouTube, MSN Messenger
Participant 3	MSN Messenger, YouTube
Participant 5	Forums
Participant 6	YouTube
Participant 7	YouTube, Flickr
Participant 8	-
Participant 9	YouTube
Participant 10	YouTube, MSN Messenger
Participant 11	YouTube, Flickr

11. Have you ever used social networks on the Internet?

Name	Response
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 5	Yes
Participant 6	Yes
Participant 7	Yes
Participant 8	No
Participant 9	Yes
Participant 10	Yes
Participant 11	Yes

12. Have you ever used content sharing services (i.e.: photo sharing, video sharing) or message sharing services (i.e.: forums)?

Name	Response
Participant 1	Yes
Participant 2	Yes
Participant 3	Yes
Participant 5	Yes
Participant 6	Yes
Participant 7	Yes
Participant 8	No
Participant 9	Yes
Participant 10	Yes
Participant 11	Yes

13. If you have used any of those

(a) Which social networks do you use?

Name	Response
Participant 1	Facebook
Participant 2	Facebook
Participant 3	Facebook
Participant 5	Facebook
Participant 6	Facebook
Participant 7	Twitter, Facebook, Hi5, LinkedIn
Participant 8	-
Participant 9	Facebook, LinkedIn
Participant 10	Hi5, Tagged
Participant 11	Facebook, Twitter, Hi5, LinkedIn

Participant 11 noted that he mostly uses Facebook and Twitter, with only some sporadic Hi5 and LinkedIn usage.

(b) How frequently do you use these networks?

1 - Never used

2 - Sporadic usage (less than once a week)

3 - Weekly usage (at least once a week)

4 - Daily usage (less than five hours a day)

5 - Intense usage (more than five hours a day)

Name	Response
Participant 1	4
Participant 2	4
Participant 3	2
Participant 5	4
Participant 6	2
Participant 7	4
Participant 8	1
Participant 9	3
Participant 10	4
Participant 11	4

(c) Which content sharing services do you use?

Name	Response
Participant 1	YouTube
Participant 2	Flickr, YouTube, MSN Messenger
Participant 3	YouTube, MSN Messenger
Participant 5	Forums
Participant 6	YouTube
Participant 7	YouTube
Participant 8	-
Participant 9	YouTube
Participant 10	YouTube, MSN Messenger
Participant 11	YouTube, Flickr

Participant 1 added that she uses YouTube to search videos to post on Facebook.

Participant 9 noted the he only uses YouTube to anonymously search for videos.

Participant 11 mentioned that he only uses YouTube and Flickr in anonymous mode, to view content.

(d) How frequently do you use these services?

1 - Never used

2 - Sporadic usage (less than once a week)

3 - Weekly usage (at least once a week)

4 - Daily usage (less than five hours a day)

5 - Intense usage (more than five hours a day)

Name	Response
Participant 1	3
Participant 2	3
Participant 3	2
Participant 5	3
Participant 6	3
Participant 7	4
Participant 8	1
Participant 9	4
Participant 10	4
Participant 11	3

14. Which of the following activities are of your interest?

Activity/Participant	1	2	3	5	6	7	8	9	10	11
Activity Following	Y	Y	N/R	Y	Y	Y	N	Y	Y	Y
News Gathering	Y	Y	N/R	Y	Y	Y	Y	Y	Y	Y
Publishing Updates	N	N	N/R	Y	Y	Y	N	Y	N	Y
Photo Sharing	Y	Y	N/R	Y	Y	Y	N	Y	N	Y
Photo Viewing	Y	Y	N/R	Y	Y	Y	Y	Y	Y	Y
Photo Archiving	Y	N	N/R	Y	Y	N	N	Y	Y	Y
Video Sharing	Y	Y	N/R	Y	Y	Y	N	N	N	Y
Video Viewing	Y	Y	N/R	Y	Y	Y	Y	Y	Y	Y
Video Archiving	N	N	N/R	Y	N	N	N	N	N	Y
Event Notification	Y	Y	N/R	Y	Y	Y	Y	Y	Y	Y
RSVP	N	Y	N/R	Y	Y	Y	Y	Y	Y	Y
Communicating with Related People	Y	Y	N/R	Y	Y	Y	Y	N	Y	Y
Music Listening	Y	Y	N/R	N	Y	N	Y	Y	Y	Y
Communicating with Musically Related People	Y	N	N/R	Y	Y	N	Y	N	Y	Y
Professional Networking	N	Y	N/R	Y	N	Y	N	Y	N	Y

Participant 1 added that she already does some photo sharing and storage through e-mail and Facebook. She also considered that professional networking isn't currently an issue of critical interest, although, she believes that in the future it might be.

Participant 2 noted that he doesn't have much interest in publishing personal information, such as Twitter or Facebook updates. He has also already used Flickr to do long term photo storage, however, very sporadically, as well as Facebook to RSVP on events. The participant has also noted that he has much interest in starting to use professional networking services.

Participant 5 already uses Facebook as a way to publish professionally oriented updates and events.

Participant 6 added that he already publishes personal updates in his blog, as well as photo sharing. He also uses e-mail to share photos, and uses e-mail and Skype to communicate with people with similar interests.

Participant 10 noted that most of his interests in the realm of social media services focus on music and video watching.

A.4 Evaluation Session

Due to timing and participant displacement limitations, it was only possible to conduct five sessions. These sessions were conducted between the days of 1 and 4 of June 2010, in Oeiras, and focused on evaluating the final mobile and desktop prototype applications, focusing on the user interaction in the fields of social network services (SNSs) and social media services (SMSs). Participants were able to interact with these prototypes through touch, voice, virtual or physical keyboard, and mouse on the desktop. A final overall evaluation questionnaire was conducted with each participant to better understand how they perceived the interaction with the prototype as a whole, as well as which improvements would they like to see in future iterations of this work. The questionnaire and responses will be presented in the following section.

A.4.1 Evaluation Questionnaire

1. Rate how difficult it was for you to use the following modalities, in accordance to this scale:

   1 - Impossible
   2 - Very Hard
   3 - Hard
   4 - Medium
   5 - Easy
   6 - Very Easy

Participant / Modality	**Computer Touch Screen**	**Computer Voice (C&C and Dictation)**	**Smartphone Touch Screen**	**Smartphone Voice (C&C and Dictation)**	**Smartphone 2D Gesture**
Participant 5	2	5	4	4	2
Participant 7	6	3	2	5	2
Participant 8	6	6	N/A	5	4
Participant 9	6	5	3	4	4
Participant 10	5	5	5	6	6

2. Rate how much you enjoyed using each of the following modalities, in accordance to this scale:

   1 - Hated
   2 - Didn't enjoy
   3 - Average
   4 - Enjoyed
   5 - Enjoyed a lot
   6 - Loved it

Participant / Modality	**Computer Touch Screen**	**Computer Voice (C&C and Dictation)**	**Smartphone Touch Screen**	**Smartphone Voice (C&C and Dictation)**	**Smartphone 2D Gesture**
Participant 5	3	3	3	3	2
Participant 7	5	3	2	5	2
Participant 8	5	4	N/A	4	5
Participant 9	5	5	4	4	3
Participant 10	5	3	3	5	5

3. Do you believe these prototypes would improve your daily tasks?

   Participant 5 answered that the mobile prototype application would be the most beneficial to him, allowing to be more independent and to better coordinate his daily tasks.
   Participant 7 believes that the prototypes allow him to interact seamlessly through different modalities, depending on his use scenarios and preferences.
   Participant 8 thinks that either of the prototypes would help him to have faster interaction with social networks, something that is becoming more important on his weekly communication activities.
   Participant 9 also believes that the prototypes would help her in her daily activities both due to the application's easy to use UI and the possibility to easily perform commands without requiring any previous training, especially with regards to voice control.
   Participant 10 said that the features and modalities offered by the prototypes would help him be more efficient in his daily tasks, allowing him to do multi-tasking, such as having the applications read his e-mail while doing other tasks.

4. Did you find the prototypes' UIs easy to use and intuitive?

   Participants 5, 7 and 10 found the UIs easy to use and intuitive.
   Participant 8 found the UI easy to use and intuitive, however added that some non-custom prompts were too small to use.
   Participant 9 believes that the prototypes were easier to use than the applications she's currently used to.

5. Which prototype application did you prefer, the mobile or the desktop version?

   Participant 5 preferred the mobile application, as he currently already has a fully functional desktop application that he's very used to. He enjoyed the mobile version a lot, as he currently isn't familiar with any mobile applications that allow this kind of interaction, and as such, found the prototype interesting.
   Participants 7 and 8 enjoyed the desktop version the most, as it offers a larger work area.

Participant 9 thought the desktop prototype has a better presentation due to it being more colourful, and because the screen had better sensitivity since it was capacitive, as opposed to the mobile device's resistive screen.
Participant 10 found the desktop prototype to be easier to use than the mobile due to its larger UI controls.

6. Which additional features would you like the prototypes to offer?

Participant 5 would like the prototype to allow music playback.
Participant 7 believes his experience with the prototype would be more complete with the addition of Facebook support, namely Wall posting, tagged photos, video, private messaging and user group support.
Participant 8 thought the prototype applications were fine the way they are, responding to her current needs.

Participant 9 would like to have more support for other social media sites and to be able to have unified contact management.
Participant 10 would like the application to offer more social shareable information like daily newspapers, weather, movies, on-line radio and music playback.

Questionnaire

Appendix B

Functional Requirements

B.1 Detailed User Requirements

The following table presents detailed information on the prototype's functional requirements, with each entry containing the requirement's title, a short description and development priority.

ID	Title	Description	Priority
R1	Desktop application speech menu navigation	Create a desktop component that interacts with a speech recognition component and executes the server specified local method, the recognition component, consisting of a voice stream receiver, a set grammars and a grammar to remote method map	P1
R2	Windows Mobile (WinMo) application speech menu navigation	Create a WinMo component that interacts with a speech recognition component and executes the server specified local method, the recognition component, consisting of a voice stream receiver, a set grammars and a grammar to remote method map	P1
R3	View SMS status updates on a Desktop	Allow a user to view his/her received and posted status updates on a selected SMS in a desktop environment	P1
R4	View SMS status updates on WinMo	Allow a user to view his/her received and posted status updates on a selected SMS in a Windows Mobile device	P1
R5	View SMS private messages on a Desktop	Allow a user to view his/her received and posted private messages on a selected SMS in a desktop environment	P1
R6	View SMS status updates on WinMo	Allow a user to view his/her received and posted private messages on a selected SMS in a Windows Mobile environment	P1

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ID	Title	Description	Priority
R7	Send a SMS private message on a Desktop	Allow a user to send a private message to one or more connected users on a selected SMS, in a desktop environment	P1
R8	Send a SMS private message on WinMo	Allow a user to send a private message to one or more connected users on a selected SMS, in a Windows Mobile environment	P1
R9	Send a SMS status update on a Desktop	Allow a user to send a status update to all connected users on a selected SMS, in a desktop environment	P1
R10	Send a SMS status update on WinMo	Allow a user to send a status update to all connected users on a selected SMS, in a Windows Mobile environment	P1
R11	Reply to a SMS message on a Desktop	Allow a user to reply to a status update or private message to one or more connected users on a selected SMS, in a desktop environment	P1
R12	Reply to a SMS message on WinMo	Allow a user to reply to a status update or private message to one or more connected users on a selected SMS, in a Windows Mobile environment	P1
R13	Forward a SMS message on a Desktop	Allow a user to forward a private message or status update to one or more connected users on a selected SMS, in a desktop environment	P1
R14	Forward a SMS message on WinMo	Allow a user to forward a private message or status update to one or more connected users on a selected SMS, in a Windows Mobile environment	P1
R15	Delete a SMS message on a Desktop	Allow a user to delete a previously sent private message or status update on a selected SMS, in a desktop environment	P1
R16	Delete a SMS message on WinMo	Allow a user to delete a previously sent private message or status update on a selected SMS, in a Windows Mobile environment	P1
R17	Write a SMS message on a Desktop using speech	Allow a user to dictate a message's content, in a desktop environment	P1
R18	Write special characters using a virtual keyboard on a Desktop	Allow a user to select and insert a special character on a virtual keyboard with simple touch or voice commands that should be inserted on the currently focused UI control	P1
R19	Search for a SMS contact on a Desktop	Allow a user to search for other users in one or more SMSs on a Desktop environment	P1
R20	Add a SMS contact on a Desktop	Allow a user to add a previously searched and selected user to his/her list of contacts on a selected SMS, in a Desktop environment	P1

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ID	Title	Description	Priority
R21	Remove a SMS contact on a Desktop	Allow a user to remove a previously added user from his/her list of contacts on a selected SMS, in a Desktop environment	P1
R22	View a SMS contact's user profile on a Desktop	Allow a user to view a search result's or a current contact's user profile on a Desktop environment	P2
R23	View a user's current contact list on a Desktop	Allow a user to view his/her current contacts list on a Desktop environment	P2
R24	View a user's current contact list on WinMo	Allow a user to view his/her current contacts list on a Windows Mobile environment	P2
R25	Update a user's profile on a Desktop	Allow a user to update his/her profile data on a Desktop environment	P2
R26	Update a user's profile on WinMo	Allow a user to update his/her profile data on a Windows Mobile environment	P2
R27	Search for published messages on a Desktop	Allow a user to search for public messages sent to a SMS, in a Desktop environment	P1
R28	Search for published messages on WinMo	Allow a user to search for public messages sent to a SMS, in a Windows Mobile environment	P1
R29	Search for published videos on a Desktop	Allow a user to search for videos published on a SMS, in a Desktop environment	P3
R30	Search for published videos on WinMo	Allow a user to search for videos published on a SMS, in a Windows Mobile environment	P3
R31	Add a local photo to a gallery on a Desktop	Allow a user to add a local photo to a managed photo gallery, in a Desktop environment	P4
R32	Add a local photo to a gallery on WinMo	Allow a user to add a local photo to a managed photo gallery, in a Windows Mobile environment	P4
R33	Add a remote photo to a gallery on a Desktop	Allow a user to add a remotely hosted photo to a managed photo gallery, in a Desktop environment	P4
R34	Add a remote photo to a gallery on WinMo	Allow a user to add a remotely hosted photo to a managed photo gallery, in a Windows Mobile environment	P4
R35	Attach a managed photo to a message on a Desktop	Allow a user to attach a locally managed photo to a new message, in a Desktop environment	P4
R36	Attach a managed photo to a message on WinMo	Allow a user to attach a locally managed photo to a new message, in a Windows Mobile environment	P4
R37	View a message's attached media on a Desktop	Allow a user to view a message's attached links, photos or videos, in a Desktop environment	P2

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ID	Title	Description	Priority
R38	View a message's attached media on WinMo	Allow a user to view a message's attached links, photos or videos, in a Windows Mobile environment	P2
R39	View photo albums on a Desktop	Allow a user to view previously created photo albums and their content, in a Desktop environment	P2
R40	View photo albums on WinMo	Allow a user to view previously created photo albums and their content, in a Windows Mobile environment	P2
R41	Manage photo albums on a Desktop	Allow a user to create new, edit and delete previously created photo albums and their content, in a Desktop environment	P2
R42	Manage photo albums on WinMo	Allow a user to create new, edit and delete previously created photo albums and their content, in a Windows Mobile environment	P2
R43	Take a picture on WinMo	Allow a user to take a picture with a Windows Mobile smartphone's camera and add it to a photo gallery or send it attached to a SMS message	P2
R44	Add a local video to a gallery on a Desktop	Allow a user to add a local video to a managed video gallery, in a Desktop environment	P4
R45	Add a local video to a gallery on WinMo	Allow a user to add a local video to a managed video gallery, in a Windows Mobile environment	P4
R46	Add a remote video to a gallery on a Desktop	Allow a user to add a remotely hosted video to a managed video gallery, in a Desktop environment	P4
R47	Add a remote video to a gallery on WinMo	Allow a user to add a remotely hosted video to a managed video gallery, in a Windows Mobile environment	P4
R48	Attach a managed video to a message on a Desktop	Allow a user to attach a locally managed video to a new message, in a Desktop environment	P4
R49	Attach a managed video to a message on WinMo	Allow a user to attach a locally managed video to a new message, in a Windows Mobile environment	P4
R50	View video albums on a Desktop	Allow a user to view previously created video albums and their content, in a Desktop environment	P2
R51	View video albums on WinMo	Allow a user to view previously created video albums and their content, in a Windows Mobile environment	P2
R52	Manage video albums on a Desktop	Allow a user to create new, edit and delete previously created video albums and their content, in a Desktop environment	P2
R53	Manage video albums on WinMo	Allow a user to create new, edit and delete previously created video albums and their content, in a Windows Mobile environment	P2

continued on next page

continued from previous page			
ID	**Title**	**Description**	**Priority**

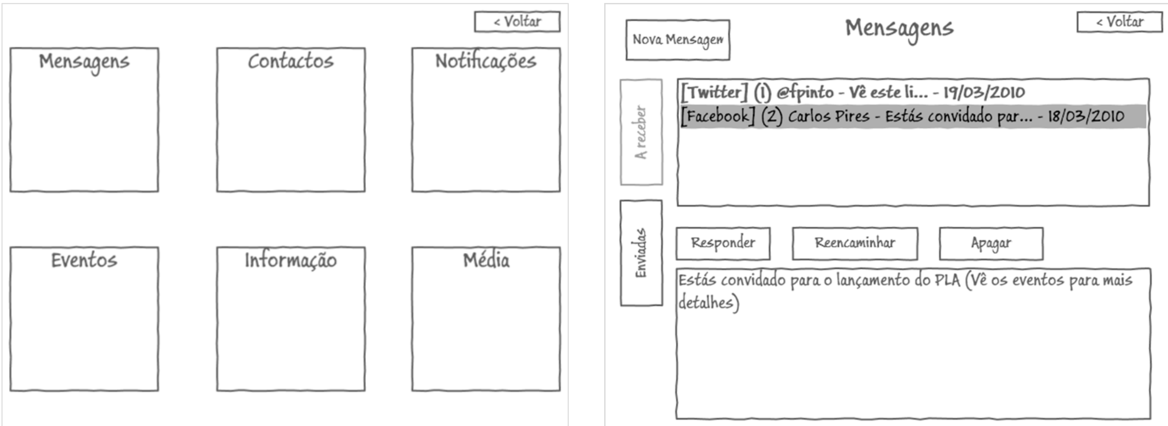
Table B.1: Functional Requirements' Table

Appendix C

Application Prototyping

C.1 Application Mockups

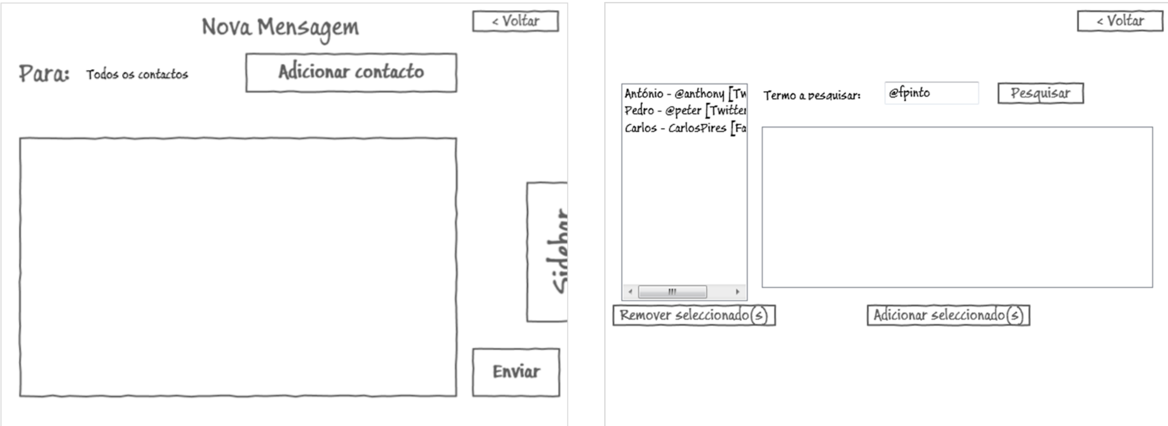
The following are early low resolution mockups, developed to better envision the prototype application's UI supported features, constraints and how to better support the non-functional requirements generated from the study's participants feedback.



(a) Main Application Menu

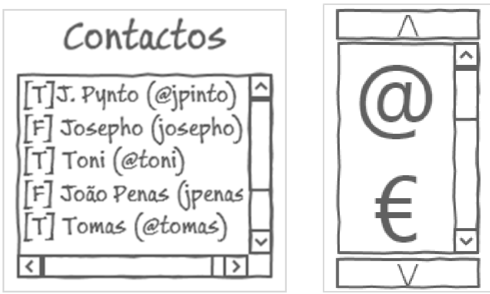
(b) Message Listing

Figure C.1: Prototype mockup screens (1/8)



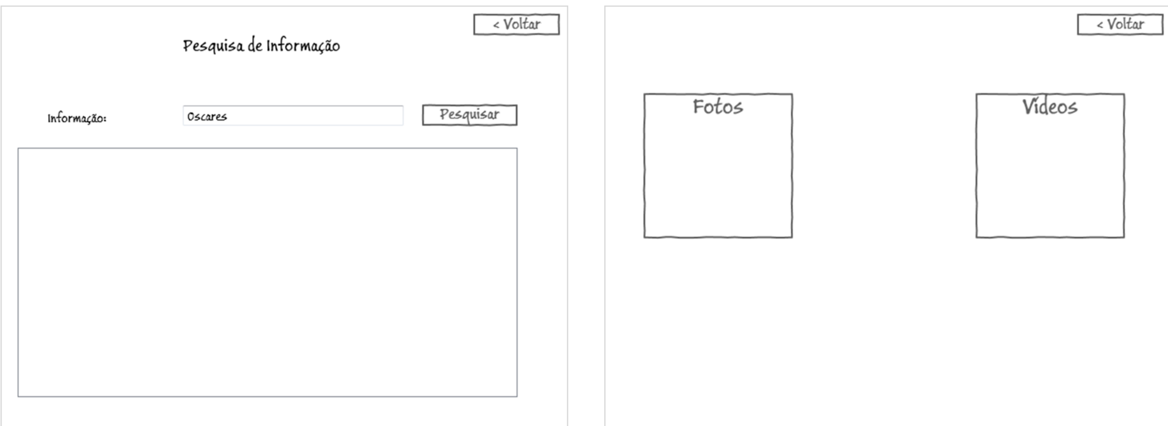
(a) New Message (b) Contact Management

Figure C.2: Prototype mockup screens (2/8)



(a) Contact Selection (b) Character Sidebar

Figure C.3: Prototype mockup screens (3/8)

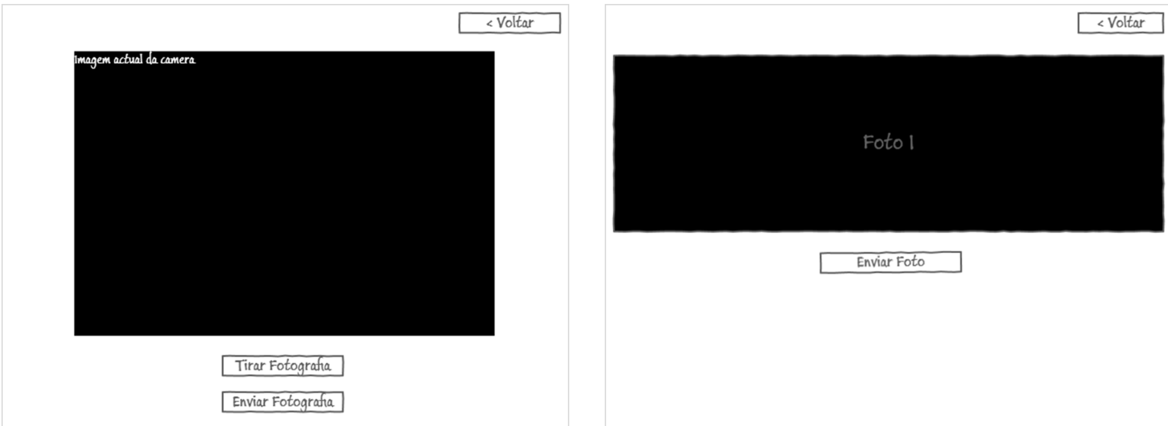


(a) Information Retrieval (b) Media Management

Figure C.4: Prototype mockup screens (4/8)

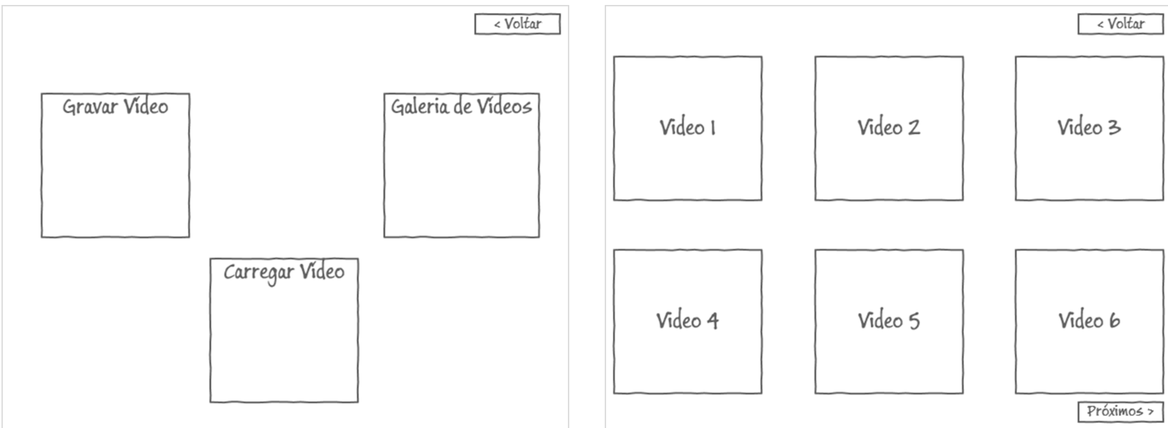
(a) Photo Management (b) Photo Gallery

Figure C.5: Prototype mockup screens (5/8)



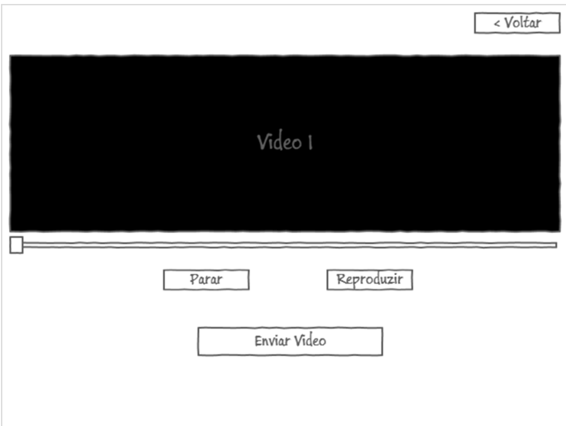
(a) Photo Taking (b) Photo Viewing

Figure C.6: Prototype mockup screens (6/8)



(a) Video Management (b) Video Gallery

Figure C.7: Prototype mockup screens (7/8)



(a) Video Viewing

Figure C.8: Prototype mockup screens (8/8)

Appendix D

Application Prototype

D.1 Prototype Application Screenshots

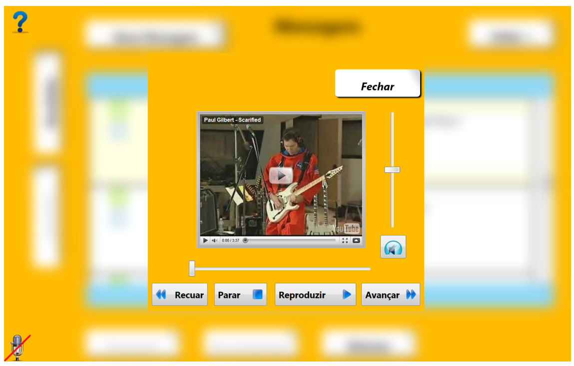
The following are screenshots taken from the final prototype application.

(a) Main Application Menu

(b) SMS Main Menu

Figure D.1: Prototype menus (1/9)

(a) Messages Listing UI



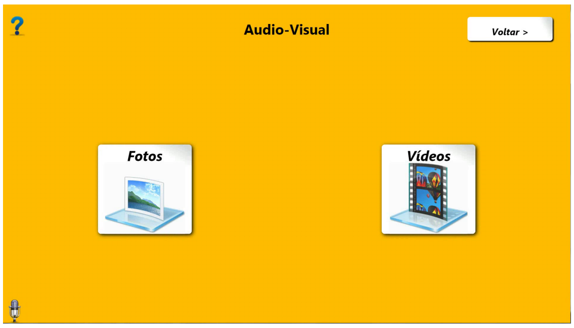
(b) Message Video Player

Figure D.2: Prototype menus (2/9)

(a) User Profile window

(b) Contact Management window

Figure D.3: Prototype menus (3/9)

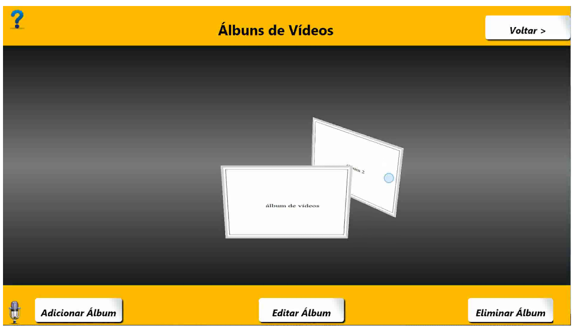


(a) Audio-Visual window

(b) New Message window

Figure D.4: Prototype menus (4/9)

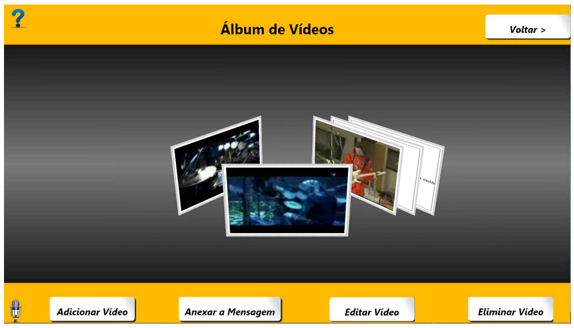
(a) Photo Albums



(b) Video Albums

Figure D.5: Prototype menus (5/9)

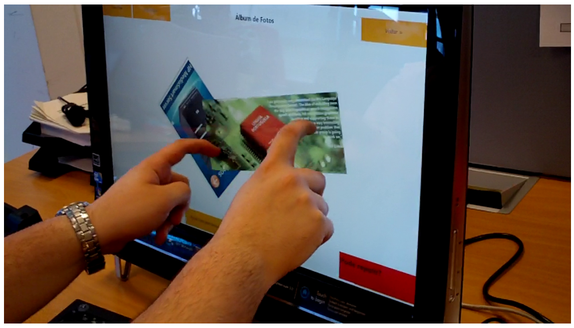
(a) Photo Album



(b) Video Album

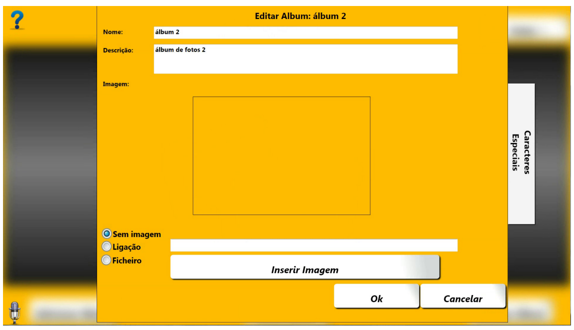
Figure D.6: Prototype menus (6/9)

(a) Multi-touch screen interaction (in the application)



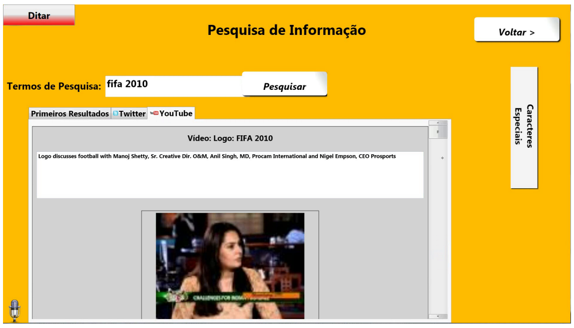
(b) Multi-touch screen interaction (with the touch screen device)

Figure D.7: Prototype menus (7/9)

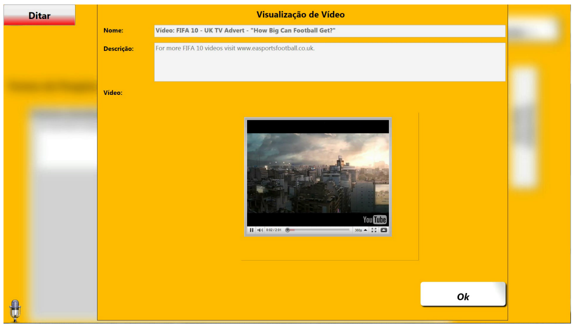


(a) Photo Album Editing

Figure D.8: Prototype menus (8/9)



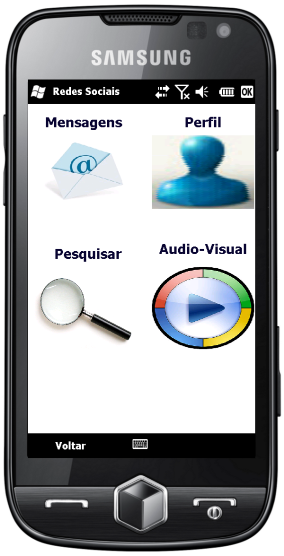
(a) Search window



(b) Search Video Player

Figure D.9: Prototype menus (9/9)

(a) Main Application Menu



(b) SMS Main Menu

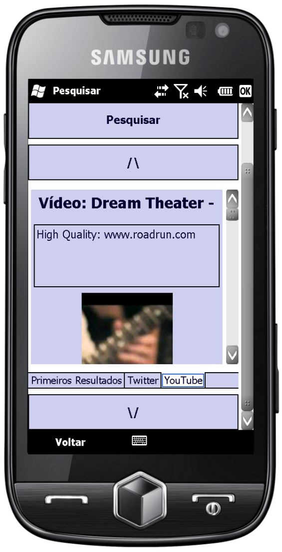
(c) Audio-Visual Content

(d) User Profile

Figure D.10: Mobile Prototype menus (1/3)

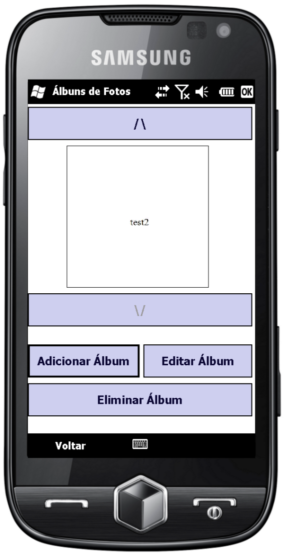
(a) Messages Menu

(b) Opened Options Menu



(c) Content Searching

Figure D.11: Mobile Prototype menus (2/3)



(a) Photo Albums

(b) Album Editing

(c) Photo Album

(d) Image Viewer

Figure D.12: Mobile Prototype menus (3/3)

Appendix E

Technologies

E.1 Social Network APIs

This appendix elaborated in greater detail additional APIs that were considered during the envision stage of the SDK, but due to popularity or technical limitations were put aside.

E.1.0.1 Last.fm

Last.fm is an on-line service that allows users to listen to music in a social way. Users can create profiles on the service, which will then be populated with information regarding their musical preferences, as they listen to music. This information can then be used to connect users with similar preferences, allowing them to recommend other songs or artists to each other. This interaction not only influences a user or a group's listening habits, but can also cause some impact on songs' and artists' relevance on the service as a whole, thus allowing other users to receive listening recommendations based on global song or artist relevance [Ltd08a].

In order for 3rd party applications to interact with this service, an API is supplied. This API can be accessed using XML-RPC or Representational State Transfer (REST) requests and replies, the latter allowing data transfers to be formatted in eXtensible Markup Language (XML) or JavaScript Object Notation (JSON). This base API allows a developer to access multiple types of data stored on the service, such as artists, albums, songs, user information, and musical event information, among others. It also allows the developer to publish information on the service on behalf of users, such as their preferences, managing their musical library, registering event attendance or updating profiles [Ltd08b, Ltd08h].

Regardless of the intent, access to the API requires at least two pieces of data: an API key, which must be requested to Last.fm, and associated with only one application, and a method, formatted as *methodGroup.methodName*. Other parameters can be specified, depending on whether the method itself requires additional information or not [Ltd08h].

Methods that change information on behalf of a user, require the user to authenticate with the service. Last.fm supplies three ways of authenticating with the service, depending on whether the application is desktop based, web based or running on a more limited mobile device.

Using the web based method, the developer must first redirect the browser to Last.fm's authentication page, sending the API key as a parameter. After the user has logged on to the service and allowed access to the application, the browser will be redirected to a developer specified callback Uniform Resource Locator (URL), to which a temporary token will be supplied. This token must then be used to request a definitive session key, which can then be used, together with the API key, to access the service on behalf of the user [Ltd08e].

Desktop based authentication is very similar to the web based process, requiring the application to first request a token to the service, using the API key. This token is sent with the API key to the service, through a web browser, where users will be asked, after logging in, if the application should be authorized to act on their behalf. After this, the application can access another service method, where it can request a session key, used in similar fashion to the one in the web application [Ltd08c].

Mobile based authentication is somewhat different from the previously described schemas. Users must supply the application with their login credentials, which are then used by the application to generate a temporary token. Using this token, the API key and the username, a session can be requested to the backend service, which can then be used like in the previous scenarios [Ltd08d].

Besides information retrieval and update in this fashion, Last.fm also supplies an API, more targeted at media playback applications, which allows users to update their music playback history with information from their own media collection, a process called *Scrobbling*. This protocol, specified in [Ltd08f], operates on a different dedicated backend system, and requires a user to authenticate using one of the above specified methods, before transferring information to the service.

To allow an easier development of applications, as with most Social Media Sites, 3rd party client libraries for this API are available, supporting development environments such as .Net, Java, C++, Ruby, PHP, Python, Perl, among others [Ltd08g].

E.1.0.2 Digg

Digg is an on-line social community geared towards content sharing and awareness, regardless of how well-known the content's origin web-site is. Users can thus post links to content, called *stories*, which will then also be voted by users, who can either *Digg* a story, which means they consider the story is of their interest, or *Bury* the story, meaning that the story either has unrelated content, bad links, or is a duplicate entry of an already submitted story. This type of interaction, coupled with the ability to comment on stories, sometimes leading to massive debates, is one of the site's social facets, with the other one being the ability to build lists of friends, as with most social media sites, which can then be used to collectively find news on the site [Inc09f, Inc09c].

As with most SMSs, Digg also supplies an API, with which developers can create 3rd party applications that interact with Digg.

Their initial API, published in [Inc09b], only allowed read usage, requiring developers to send their requests through one of several endpoints, along with a developer-chosen application key. Responses were then returned in one of four formats, depending on the developer's chosen content type, which can be standard XML or JSON, as well as JavaScript or Serialized PHP [Inc09d]. As with most APIs, client libraries have been developed by community members to further ease development efforts. Supported development environments included Java, .Net, PHP, Perl, Python or Ruby [Inc09e]. This API has been marked as deprecated since October 2009, and has been replaced with a new, extensible API, supporting both read and write operations on the backend service.

Digg's new API is also REST based, supporting, as with their previous API, responses formatted in XML, JSON and JavaScript. The endpoint access methods have, however, been changed to support not only concurrent versions with different functionalities, but also to support write access to the API. Read access can be performed by simply calling one of several methods the API supplies, which are organized in method groups, in similar fashion to Last.fm's API. Write access requires developers to register their applications with Digg, after which, they will receive a consumer key and secret. This pair must then be used to establish a session with the service, on behalf of a Digg a user, using the OAuth authentication protocol. In a similar way to Last.fm's API, the application must first get a temporary token from the backend and redirect the user to a login page, attaching the token to the request. The user must then authorize the application to act on his/her behalf, and afterwards, supply a backend generated verification code to the application. This verification code, along with the initial token, allows the application to retrieve an access token from the backend, which can be used to submit information to the backend service [Inc10e, Inc10c].

Since the newer API is still very recent, support for client libraries is practically non-existent. As such, currently only two development environments are fully supported, PHP [Inc10f] and .Net [Pin10], with some Java code available in the APIs' support community, for specific applications [Inc10d].

E.1.0.3 Flickr

Founded in 2004, Flickr is currently an image and video clip hosting service that allows its users not only to host content, but also to organize it through a form of metadata called tags, as well as through sets of photos and videos, which can then be grouped together into content collections. On a social facet, Flickr allows users to share content with family and/or friends, as well as maintaining and joining user groups focused on certain subjects, with which they can share photos and comment on each other's photos [Inca].

Flickr's API is divided into two types of operations: photo uploading and data access/manipulation. The first type of operation requires the 3rd party application to act on behalf of a user by authenticating with the service. After authentication, the application must send a signed POST request with the photo's binary content and some arguments regarding the photo's metadata to be used in Flickr. Under regular circumstances, an XML formatted REST response will then be returned to the application with the photo's id on Flickr [Incc]. The data API can be accessed, as with the previous two API's, through a set of methods encased in method groups as described in [Inc10z]. Requests to these methods can be thus made as REST requests, XML-RPC calls or Simple Object Access Protocol (SOAP) requests. Responses are, by default, returned in the same format as the request, however, the developer can specify a format argument in the request, so as to override the format to one of the following response formats: XML, XML-RPC, SOAP, JSON, or Serialized PHP.

Flickr's authentication schema is not as straightforward as previously described schemas. The developer must first request an API Key and respective shared secret, through the creation of an application entry in Flickr's *App Garden* environment. While creating this record, the developer must also choose whether the application is desktop, web or mobile based [Incd].

Figure E.1: Digg's OAuth authentication flow (Source [Inc10c])

API methods are divided into four access categories, depending on the type of permission required to access their data. Public methods don't access sensitive user data, and as such, don't require any authentication, with the developer only needing to supply the application's API key, method to invoke and method parameters as required. Methods that access sensitive user data require the application to act on behalf of the user, thus, the application must obtain an authentication token from Flickr's backend service, which can then be used, along with the API key, to access restricted data. Another class encompasses methods that manipulate backend information. These methods require the user to authenticate and grant write permissions to the application. The fourth class currently only refers to one method, photo deletion. Since photos are considered crucial data for Flickr, this action requires delete permission from the user, which must also be granted during authentication [Incb].

Regarding the authentication process itself, Flickr's specification closely resembles Last.fm's, requiring a developer to request an API key and a shared secret. Web, desktop and mobile applications are supported through three different types of procedures. Web applications' authentication requires the developer to send users to a Flickr login URL, specifying the API key, required access permissions and a signature, the latter signed with the shared secret. After logging in, users will be redirected to a developer specified callback URL, which will receive, as a parameter, what Flickr calls a *frob*. This is a temporary token that must be exchanged, through a call to the API, with a session token, which can then be used to make successive API calls with the required permissions. Desktop applications' authentication is very similar to web based authentication however, the developer must first request a *frob* from the API, which must then be sent as a parameter in the login URL, so the backend service can identify the login session. Due to limitations in mobile devices' development environments, authentication requires an alternate approach. The developer must first redirect the user to a previously specified static Flickr authentication URL. There, users will be required to login to Flickr, receiving afterwards a 9 digit *mini-token*. This token should then be supplied to the application, which can then use it to request a full token from the API, so it can make authenticated calls to the API [Incb].

Several client libraries, defined by Flickr as *API kits*, also exist, supporting development environments such as C, Java, .Net, Perl, PHP, Python or Ruby [Inc10z].

E.1.0.4 LinkedIn

LinkedIn is a business oriented professional network site, allowing users to maintain connections with people they know and trust in their professional area. It can also be used by employers to list jobs and find potential candidates, as well as by job seekers.

LinkedIn's API is REST based, and is divided into six different domains: user profiles, user connections, service search, invitations, status updates and network updates. With the exception of the invitations and status updates domains, all other domains are purely REST based, requiring developers to send GET or POST requests to the service endpoint, which will reply with XML formatted responses, as per specification. Both those domains require the developer to send XML data respectively encased in a POST or a PUT request [Cor10h, Cor10d]. The profile domain allows developers to access, after authenticating with the service, user profile information, be it the application user's profile or a known user [Cor10g]. As with most methods in this API, a limited amount of data is supplied on a default call, so bandwidth consumption can be reduced. Developers must thus, explicitly specify on their requests any additional data they require using *Field Selectors*, as per [Cor10b]. The connection domain methods also require authentication, and allow access to the authenticated user's connections, that is, other users who are known by the requester [Cor10a]. The search method allows data search in LinkedIn by simple keywords, company information, user profile data, among others, by simply specifying this data in the search URL, as parameters. Due to the massive amount of data available on the backend database, pagination is used to avoid reception of overwhelming amounts of data [Cor10f]. The invitation method allows an authenticated user to invite other LinkedIn users to join their extended user network, composed of all connections the user has with other network users, be they direct connections or through 3rd parties [Cor10d]. Status update methods allow users to post short messages, with a similar purpose to Twitter's status updates, as well as retrieving their own or other users' status messages [Cor10h]. Network update methods, on the other hand, allow users to access status updates from all first degree connected users, that is, users with whom they share direct connections in LinkedIn, and not connections by proxy. These methods also allow users to explicitly send broadcast messages, targeted at all first degree connected users [Cor10c, Cor09b].

As already mentioned, this API always requires the existence of an authenticated user session. As with some SMSs already mentioned, LinkedIn adopted OAuth, requiring developers to register their applications with the service, which will supply a consumer key and shared secret. This information can then be used to retrieve an initial request token and, after user authentication, an access token, that can be used to make future authenticated calls to the API [Cor10e].

To avoid performance issues with the API response, as with Twitter, LinkedIn imposes certain limitations on the amount of daily calls that can be made to specific API methods. These limits are imposed both on a user-by-user basis, and on an application key basis, as further elaborated in [Cor10i].

Although not as abundant as with other APIs, client libraries developed in Java [Muk10], .Net [Bee10], Ruby [Net10] and PHP [Pee09] exist for LinkedIn. This is easily justifiable, as LinkedIn has only opened its API to the public in November 2009 [Cor09a].

E.1.0.5 Facebook

Facebook is a generalist social network site that allows users to define their own on-line profiles, build friend communities, send them messages, and notify them of changes in their lives, through personal profile updates. Users can also share photos, be notified and *Répondez s'il vous plaît* (RSVP) on events, join closed networks on Facebook, according to city, workplace or education facility. With the launch of the Facebook platform in 2006, software developers were able to build applications focused on the site, allowing users to access Facebook from a variety of devices and contexts, as well as using site-centred applications in a collaborative way [Fac10i]. Developers can thus create standalone applications that access Facebook's API, web-based applications that communicate with the service through Facebook connect, or applications that are directly integrated within Facebook, appearing as another of the site's pages.

Facebook integrated applications, also known as Canvas applications, can either be developed using their own Hyper Text Markup Language (HTML) and JavaScript based dialects, respectively called FaceBook Markup Language (FBML) and FaceBook JavaScript (FBJS), or using IFrames. FBML with FBJS allows the development of fast, powerful, yet somewhat limited applications. IFrame based applications are somewhat slower, since they traditionally require the developer's server to explicitly make API calls to Facebook, while FBML based applications can just use FBML place-holders, leaving the work of data filling for Facebook's FBML processor. The appearance of the eXtensible Facebook Markup Language (XFBML) made it possible to integrate FBML place-holders in IFrame applications, allowing the combination of XFBML with regular HTML code, JavaScript and Cascading Style Sheets (CSS), something that is not possible with regular FBML code [Fac09a].

Developers can also directly integrate Facebook data into existing web applications using XFBML in their eXtensible Hyper Text Markup Language (XHTML) pages, and Facebook connect as a way to authenticate their users with Facebook, thus allowing 3rd party applications to access users' profile information, and acting on their behalf on Facebook, without requiring direct access to users' login credentials [Fac10h].

Standalone applications can be developed either using direct communication with a REST API or through a Facebook SQL-like language called Facebook Query Language (FQL). API access requires an application to first authenticate with Facebook, allowing developers to access user data, as well as posting comments, links, notes, status updates, photos or even events. The FQL language abstracts the API access process, allowing easier interaction with Facebook [Fac09b, Fac10o, Fac10l].

Facebook supplies several ways of authenticating and authorizing users, so as to allow application access to the service on behalf of users. Regardless of the type of application, developers must first register them with Facebook, creating an application profile that can be viewed by users. This process will supply the developer with an API key and shared secret, in all similar to the ones used in previously described SMSs [Fac10m]. Also, since Facebook's developer policy requires that applications don't store user login credentials, one of the several available on-line login methods must be used, as described below [Fac10p].

Canvas applications can authenticate users through one of four methodologies. Developers can use one of the many unofficial client libraries published in [Fac10f], which already offer support for authentication, as well as API abstraction. Users can be redirected to Facebook's login page by the application, which will return them to a developer specified page on success. Developers can also request authentication on a feature by feature basis, by specifying a *requirelogin* attribute on links or forms in the canvas page. Finally, the developer can also use FBML on the page which, when processed by Facebook's backend service, will be used to verify if the user is logged-on or not, redirecting to the login page if necessary [Fac10d].

Web and desktop applications must use Facebook connect to authenticate with the backend service. Developers must thus either redirect users to Facebook's login page, specifying a callback URL, or in the case of desktop applications, show a popup web control inside the application, specifying as a callback URL the default *login successful* Facebook page. In either case, after the session has been established, developers will have access to a session key, supplied as a parameter on the callback URL that can be used to make further API calls [Fac10e]. Mobile applications must use a similar process, accessing however, a mobile device specific page, as specified in [Fac10c]. In all of these situations, if users haven't yet authorized the application to access their profiles, Facebook will make an explicit request, after the log-in. Also, developers can request additional permissions on an application-by-application basis, should they require access privileges that the user normally doesn't allow on every application. These include accessing the profile while the user is offline, publishing content on their behalf or accessing user specified private information [Fac10e, Fac10c, Fac10g].

As already mentioned, Facebook supplies a large amount of unofficial client libraries to further simplify application development. These support development environments such as Java, .Net, PHP, Perl, Python, Ruby, Windows Mobile or Android.

In April of 2010, Facebook released their newest iteration of the Facebook Platform. This evolution introduced new, simpler and more powerful means of development such as Social Plugins and the Graph API [Fac10j]. The Graph API in effect allows developers to have more control over how they access and publish content, allowing access to previously unavailable features such as photo and video albums, or user profile management, by simply navigating a graph where each node (called an object in Facebook terminology), contains all publicly available information regarding that object. Information retrieved or updated in this manner is now formatted in lightweight and easy to process JSON [Fac10n]. Facebook also made the leap, in this iteration, as most major social media sites, into OAuth authentication support. Although support for this authentication method was also extended into the older REST API, as well as FBML and FQL, Facebook now strongly recommends newer developers to adopt their more powerful and simpler Graph API [Fac10o, Fac10k].

E.1.0.6 Summary

The in-depth analysis made on the previous sections demonstrates several key points on additional SMSs' APIs and means of development. The following table thus summarizes this information, focusing on development formats, client libraries, authentication schemas and API types, with the intent to show where these APIs converge and diverge.

Social Network	Domain	API	Formats	Functionalities	Platforms	Environments	Authentication
Last.fm	Music	Data Query	REST (XML, JSON) XML-RPC	Album, Artist, Event, Library, Playlist, Song, User, User Group (query and manipulation)	Desktop	.Net, C++, Java, Objective-C, Python	API Key + Token + Session Key
					Web	.Net, Flash, Java, JavaScript, Perl, PHP, Python, Ruby	API Key + Token + Session Key
					Mobile	.Net (Win. Mobile), Java (Android), Objective-C (iPhone)	User credentials + API Key + Token + Session Key
		Scrobbling	REST (Last.fm SP)	Listening Habits Submission	Desktop	.Net, C++, Java, Objective-C, Python	API Key + Token + Session Key
					Web	.Net, Flash, Java, JavaScript, Perl, PHP, Python, Ruby	API Key + Token + Session Key
					Mobile	.Net (Win. Mobile), Java (Android), Objective-C (iPhone)	User credentials + API Key + Token + Session Key
Digg	News	Data Query and Update	REST (XML, JSON, JavaScript)	Comment, Container, Dialogg, Digg, Media, Story, User (query and manipulation)	Desktop	.Net, Java	OAuth
					Mobile	.Net, Java	OAuth
					Web	.Net, Java, PHP	OAuth
Flickr	Photos	Data Query and Update	REST (XML, JSON, PHP) XML-RPC SOAP	Gallery, Photo, Tag, User, User Group (query and manipulation)	Desktop	.Net, C, Java, Objective-C, Python	API Key + Frob + Token
					Web	.Net, Flash, Java, Perl, PHP, Python, Ruby	API Key + Frob + Token
					Mobile	.Net (Win. Mobile), Objective-C (iPhone)	API Key + Mini-Token + Token
		Data Uploading	REST (POST Request)	Photo Uploading	Desktop	.Net, C, Java, Objective-C, Python	API Key + Frob + Token
					Web	.Net, Flash, Java, Perl, PHP, Python, Ruby	API Key + Frob + Token
					Mobile	.Net (Win. Mobile), Objective-C (iPhone)	API Key + Mini-Token + Token
LinkedIn	Business networking	Data Query and Update	REST (XML)	Connection, Invite, Network Update, Service, Status Update, User (query and manipulation)	Desktop	.Net, Java	OAuth
					Web	PHP, Ruby	OAuth
					Mobile	Java (Android)	OAuth
Facebook	Generic	Data Query and Update	Canvas Application	Community, Profile (query and manipulation) Message and Notification sending Photo sharing Event and Profile updating	Web (FBML)	FBML + FBJS + (.Net, Flash, PHP, Perl, Python, Ruby)	OAuth, FBML, Token Authentication, Client Library
					Web (Iframe)	XHTML + XFBML + (.Net, Flash, PHP, Perl, Python, Ruby)	OAuth, XFBML, Token Authentication, Client Library
			External Web Applicaton		Web	XHTML + XFBML + (.Net, Flash, PHP, Perl, Python, Ruby)	OAuth, Facebook Connect
			REST (XML, JSON)		Desktop	.Net, C++, Java, Objective-C, Python	OAuth, Facebook Connect
					Web	.Net, Flash, PHP, Perl, Python, Ruby	OAuth, Facebook Connect
					Mobile	.Net (Win. Mobile), Java (Android), Objective-C (iPhone)	OAuth, Facebook Connect (Mobile Pages)
			Graph API	Album, Event, Group, , Note, Page, Photo, Post, Shared Link, Status Message, User and Video management	Web	.Net, JavaScript, PHP, Python	OAuth
					Desktop	.Net, Python,	OAuth
					Mobile	Java (Android) Objective-C (iPhone)	OAuth

Figure E.2: Social Media Services API Comparison (addendum)

Appendix F

Evaluation Data

F.1 Detailed Requirements Gathering Task Listings

The following set of lists contains the scripted tasks used for each SMS. The script for each participant's chosen task was dictated to minimize the temporal effect of reading and interpretation by each participant.

Task	Task Description
1.	Access the website http://www.twitter.com
2.	Login with the provided test account
3.	Access your user profile and update your name and time zone
4.	Start following user *RTPNoticias*
5.	Send a *Tweet* (general message)
6.	Reply to one of the messages sent by *RTPNoticias*
7.	*Retweet* (Forward) a message sent by *RTPNoticias*
8.	Go to twitpic.com and login with the test account
9.	Use this service to send a *Tweet* with photo *teste* (available on your desktop) attached
10.	Open search.twitter.com and search for *Oscar* related information
11.	Launch the *Windows* application *DestroyTwitter*
12.	Send a *Tweet* through this application
13.	Search for *Oscar* related information on this application

Table F.1: Twitter.com tasks

Task	Task Description
1.	Access the website http://www.facebook.com
2.	Login with the provided test account
3.	Access your user profile and update your name and birthday
4.	Send the video *Fighting Cats* (available on your desktop) to Facebook
5.	View the video you just sent
6.	Upload photo *teste* (available on your desktop) and create a photo album on Facebook
7.	View the uploaded photo
8.	Search and add user *fernandomiguelpinto* as your friend on Facebook
9.	Send a private message to the previously added user: Text: O meu e-mail é: apmultimodal@gmail.com
10.	Send a message to previous user's wall: Text: Deixa cá ver se escrever o símbolo de euro é difícil: €

Table F.2: Facebook.com tasks

Task	Task Description
1.	Access the website http://www.youtube.com
2.	Login with the provided test account
3.	Access your user profile and update your name and country
4.	Send the video *Fighting Cats* (available on your desktop) to YouTube
5.	View the video you just sent
6.	Search a video that interests you
7.	View the selected video
8.	Subscribe the video uploader's channel
9.	View your subscriptions
10.	Create a playlist
11.	Add the video *Fighting Cats* to the newly created playlist

Table F.3: YouTube.com tasks

Task	Task Description
1.	Access the website http://www.flickr.com
2.	Login with the provided test account
3.	Access your user profile and update your name and country
4.	Send photo *teste* (available on your desktop) to Flickr
5.	View the photo you just sent
6.	Search user *apmultimodal1* and add him as your friend
7.	Create a photo gallery
8.	Search for user group *HDR* and join that group
9.	View some photos published to that user group

Table F.4: Flickr.com tasks

Task	Task Description
1.	Access the website http://www.last.fm
2.	Login with the provided test account
3.	Access your user profile and update your name and country
4.	Search for the artist *The Killers* and listen to some of their music
5.	View related music videos
6.	Search for events happening in Portugal
7.	Launch the *Windows* application *Last.fm*
8.	Search for the artist *The Killers* on the application you opened and listen to some music
9.	Check the first song as one that you like
10.	Skip to the next song
11.	Check the second song as one that you dislike

Table F.5: Last.fm tasks

Task	Task Description
1.	Access the website http://www.linkedin.com
2.	Login with the provided test account
3.	Access your user profile and update your name and country
4.	Search and add the following users to you contact network: *Salvador Mendes de Almeida*, *Fernando Miguel Pinto*.
5.	Search for and join the user group *Associação Salvador - Grupo de Teste*

Table F.6: LinkedIn.com tasks

Task	Task Description
1.	Access the website http://www.digg.com
2.	Login with the provided test account
3.	View a news that's on the main page of Digg
4.	Search for a popular news
5.	Vote that news up (Digg it)
6.	View a news that's published in the Soccer category

Table F.7: Digg.com tasks

F.2 Detailed Requirements Gathering Analysis Results

This section presents the results of the interaction analysis done over the second user study. Due to time constraints, users were only able to test one social media service, and as such, results will be grouped by service and not all services were tested. These will also be divided into qualitative and quantitative results. Qualitative results will present observations made both by the participant and the researcher as well as an overall result. This result can either represent successful completion of the task at hand, completion of the task with some execution errors noted during the procedure, unsuccessful completion of the task due to the participant exceeding the maximum allowed execution time or *N/A*, which represents that the participant did not execute the task at all. Quantitative results present concrete results such as how long a participant took to complete a task or how many times the research had to intervene to help him in a particular task.

F.2.1 Twitter Tasks

Participant	**Has used before?**	**Result**	**Time to task completion (minutes:seconds)**	**Number of aids**
Control	Yes	Completed successfully	07:05	0
Participant 2	No	Completed with errors	14:11	3
Participant 8	No	Completed successfully	11:42	5
Participant 9	No	Completed successfully	10:04	0

Table F.8: Twitter.com interaction evaluation results (part one)

Participant	**Researcher Observations**	**Participant's opinions**
Participant 2	Participant used the service with very little difficulty, however, he had some issues finding out how certain features worked.	Participant believes that her issues were derived from never having used the service before
	Participant used the *Tweet* feed search to find people instead of the people finding search option	Participant believes that Twitter's service is not very intuitive, considering it at most *Functional*
	Participant had some issues typing special characters such as @	Participant believes that Twitter is interesting for someone like him who wants to keep up with news and information
	Participant used additional twitter services such as *twitpic* and Twitter's search engine without a problem	Participant believes that filtering and instant updates are interesting features in Twitter that give the service some added value

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Participant	Researcher Observations	Participant's opinions
	Participant has some issues using the Twitter application *DestroyTwitter*, namely sending a *Tweet*	Participant believes that voice interaction would benefit in both command & control and dictation, as he can more easily elaborate short messages when speaking than when writing
Participant 8	Participant had many difficulties finding components in the service and associated application Participant isn't very used to how a browser works Once logged in, Participant was able to find more visible operations like *Tweet*, *Re-Tweet* or *Reply* Participant was unable to use *DestroyTwitter* on her own, mostly due to hard to read and find controls in the application	Participant believes that his issues were derived from never having used the service before
Participant 9	Participant didn't have significant issues using either user interface (UI) Participant evidenced some proficiency in using social media services as no help was needed	Participant found that both UIs were easy to use Participant found however that *DestroyTwitter's* UI was too small and very dark, making it somewhat unappealing

Table F.9: Twitter.com interaction evaluation results (part two)

F.2.2 Facebook Tasks

Participant	Has used before?	Result	Time to task completion (minutes:seconds)	Number of aids
Control	Yes	Completed successfully	08:50	0
Participant 3	No	Incomplete	12:10	2
Participant 7	Yes	Completed successfully	12:57	2
Participant 11	Yes	Completed successfully	10:29	1

Table F.10: Facebook.com interaction evaluation results (part one)

Participant	Researcher Observations	Participant's opinions

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Participant	**Researcher Observations**	**Participant's opinions**
Participant 3	Participant had many difficulties finding his way around the service's site Participant found video and photo management functionalities by association, something that most other participants couldn't find by themselves Participant didn't complete the task due to time constraint issues Participant had some difficulties concentrating on the task at hand, which made it difficult to find some simple elements	Participant thought that the service overall wasn't too difficult to use Participant believes that with some additional tries he could properly execute the proposed tasks
Participant 7	Participant demonstrated some experience using SMSs. Overall the participant didn't have many issues interacting with FB Participant didn't have an issue with CAPTCHA's It was hard for the participant to find out how to send private messages over FB. Friends list is in a *low real-estate* area of FB's home page, and as such, the participant didn't find his FB friends very easily	Participant believes that Facebook's (FB) interface is somewhat complex to use. Participant mentioned that information retrieval (IRET) was unintuitive Participant added that the existence of many links in the same page can make IRET some difficult Participant thinks that the usage of alternative modalities such as speech would benefit tasks like message writing and application retrieval, as well as reducing the amount of time he needs to move his hands
Participant 11	Participant completed this task without having significant issues Participant was very proficient with Facebook's UI, something that was clear from how he found options with little effort and almost instantly Participant used Facebook's CAPTCHA without any issues	Participant believes voice would help him better use social media services Participant however believes that he would use voice somewhat more in dictation mode than in command and control

Table F.11: Facebook.com interaction evaluation results (part two)

F.2.3 YouTube Tasks

Participant	**Has used before?**	**Result**	**Time to task completion (minutes:seconds)**	**Number of aids**
Control	Yes	Completed successfully	04:46	0
Participant 6	Yes	Incomplete	15:30	7
Participant 10	Yes	Completed successfully	07:30	1

Table F.12: YouTube.com interaction evaluation results (part one)

Participant	**Researcher Observations**	**Participant's opinions**
Participant 6	Participant was unable to find some links. Found them too small.	Participant said he didn't have too much experience with YouTube's user functions, using it only for video viewing
	Participant found that having options in a drop down menu on the username wasn't very intuitive	Participant thought that YouTube's pages had too much information and fonts were too small. As such, operations were hard to find and execute
	Participant had difficulties finding playlists	Participant was also somewhat confused with dynamic pages (AJAX based), finding them hard to navigate
	Due to excessive navigation time, the participant was told to abort the task near the end	
Participant 10	Participant had no significant issues using the service	Participant found the service easy to use
	Participant took some time to find specific profile data inside the profile options menu due to the overwhelming amount of selectable options	Participant believes that additional interaction modalities like voice or touch wouldn't bring him a lot of advantages in this particular service
	Participant took some time to find how to add a video to a playlist since the option wasn't too intuitive	Participant later found, during modality testing, that voice interaction would be very useful in command and control mode, adding that he would like to use it in more complex interaction scenarios

Table F.13: YouTube.com interaction evaluation results (part two)

Participant	Has used before?	Result	Time to task completion (minutes:seconds)	Number of aids
Control	Yes	Completed successfully	06:40	0
Participant 1	No	Completed successfully	10:13	0

Table F.14: Last.fm interaction evaluation results (part one)

F.2.4 Last.fm Tasks

Participant	Researcher Observations	Participant's opinions
Participant 1	Participant found her way around the service's site without a problem, although taking some time to execute tasks due it being her first use of the service	Participant enjoyed Last.fm's functionalities
	Last.fm's service had some issues with video search, but the participant found her way around the issue by herself	Participant enjoyed the service's site however, found the scrobbler application unappealing and confusing to use
	Participant had some difficulties on finding the *love* and *ban* features on the Last.fm scrobbler application, but ended up finding these options without help	Participant believes that voice interaction would help reduce the service's learning curve and allow a seamless interaction with it

Table F.15: Last.fm interaction evaluation results (part two)

F.2.5 Summary

The tasks performed by this study's participants, that is, those executed in social media services Twitter, Facebook, YouTube and Last.fm, can overall be divided into two main subgroups: message-centric services, with Twitter and Facebook fitting into this category, and media-centric services, with YouTube and Last.fm fitting in this category.

F.3 Detailed Hardware Use Requirements Gathering Analysis Results

Modality	Results
3D Gesture	Participant found it impossible to adequately grip the smartphone.
Keyboard	Participant was able to write on the keyboard with only one finger at a time and had to use her knuckles (see Figure F.1(a)).
Mouse	Participant is more used to using a trackpad but used a regular mouse with both hands (see Figure F.1(b)).
Multitouch	Participant found it impossible to simulate simple multi-touch gestures on the tablet PC's screen.
Speech (European Portuguese)	Participant can place the headset correctly and with ease. Participant however finds it easier to place an earpiece than a headset. Participant had no issues using the ASR engine and expressed great interest in using ASR in command & control, as well as in dictation mode.
Tablet PC Stylus	Participant was unable to use the stylus on a vertically placed screen. Participant was able to use the stylus on a horizontally placed screen with some difficulty (see Figure F.1(c)). Participant, however, found that handwriting was impractical due to the level of pen pressure needed to write something on the screen.
Touch Screen (Smartphone)	Participant could only use the smartphone on a fixed surface, and even then was unable to correctly use 2D gestures. Participant was also unable to properly select items on the touch screen since selectable icons were too small.

Table F.16: Participant 1 interaction evaluation

(a) keyboard interaction (b) mouse interaction (c) stylus interaction

Figure F.1: Participant 1 hardware interaction

Modality	Results
3D Gesture	Participant managed to hold the smartphone with some difficulty. After getting a firm grip on the phone, the participant (see F.3(c)) was able to correctly use the *Dice Game*.
Keyboard	Participant is able to write with both hands using two finger knuckles at a time (see Figure F.2(a)). Participant also has a habit of writing by holding one pen or pencil with each hand (see Figure F.2(b)), using as typing handles. With this latter mechanism the participant is able to double his writing speed.
Mouse	Participant is only able to get a proper grip of a mouse with his left hand, holding it with two of his fingers (see Figure F.3(a)). After managing a proper grip the participant is able to operate the mouse without a problem.
Multitouch	Participant found it impossible to do gestures with multiple fingers with either one or two hands. Participant explained that this is a common issued with quadriplegic individuals as it's very hard for them, if not impossible to some, to have both arms in the air.
Speech (European Portuguese)	Participant can place the headset correctly and with ease. Participant had no issues using the ASR engine and expressed great interest in using ASR in command & control, as well as in dictation mode.
Tablet PC Stylus	Participant is able to correctly use the stylus when the tablet PC is placed horizontally on his lap (see Figure F.3(b)). Participant found handwriting as easy to use as a keyboard.
Touch Screen (Smartphone)	Participant had some difficulties managing a steady grip of the smartphone. After getting a steady grip, the participant correctly used the touch screen with both hands, managing to scroll with one of his finger's knuckles (see F.3(c)). The participant found that icon selection was somewhat hard, suggesting that icons should be larger to allow more imprecise motion.

Table F.17: Participant 2 interaction evaluation

Modality	Results
3D Gesture	Participant managed to correctly use the smartphone's accelerometer.
Keyboard	Participant used the keyboard without any issues, however, only used one finger to write since he isn't very proficient with computers.
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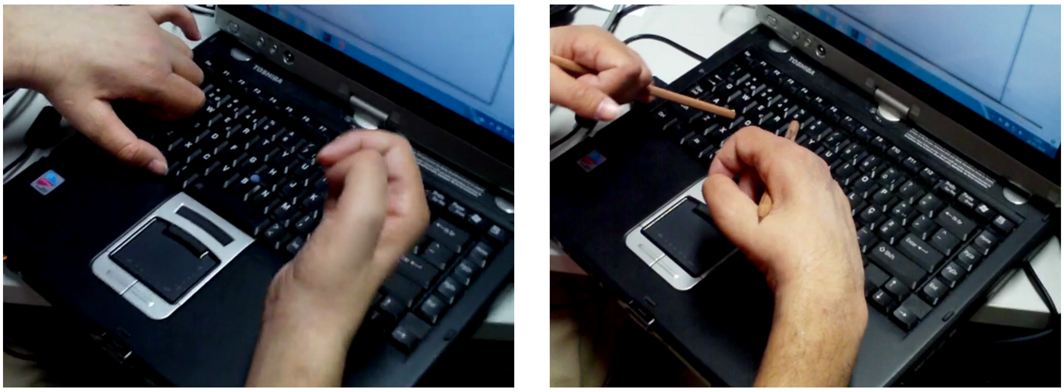
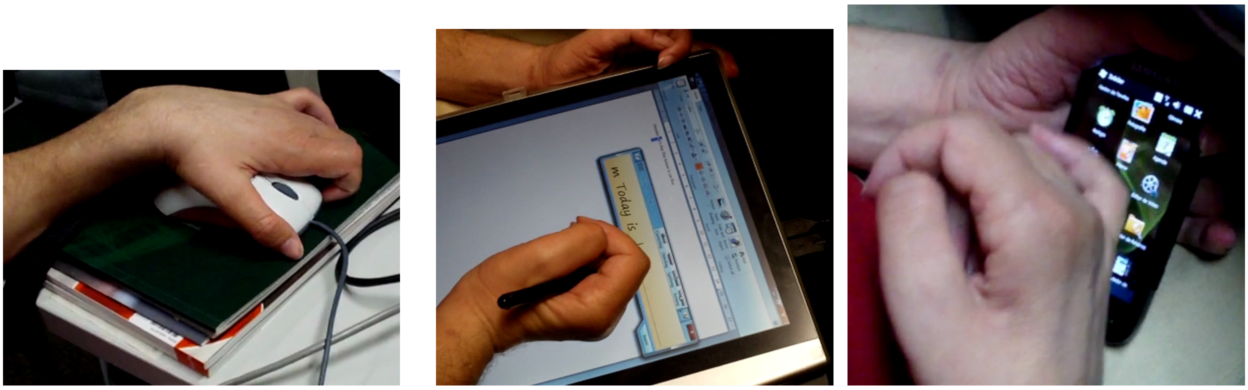


(a) keyboard interaction with knuckles (b) keyboard interaction with pencils

Figure F.2: Participant 2 hardware interaction (part one)



(a) mouse interaction (b) stylus interaction (c) smartphone interaction

Figure F.3: Participant 2 hardware interaction (part two)

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Modality	Results
Mouse	Participant managed to use correctly and with ease the computer's mouse.
Multitouch	N/A
Speech (European Portuguese)	N/A
Tablet PC Stylus	N/A
Touch Screen (Smartphone)	Participant managed to use correctly and with ease the smartphone's touch capabilities.

Table F.18: Participant 3 interaction evaluation

Modality	Results
3D Gesture	Participant found it impossible to adequately grip the smartphone.

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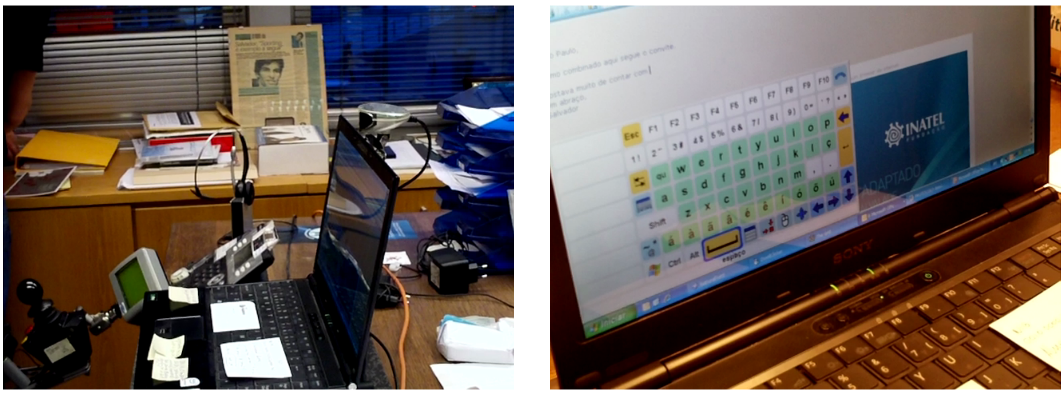
Modality	Results
Keyboard	Participant was unable to use a keyboard due to his degree of physical limitations, however, was able to write with a virtual keyboard through an eye-gaze detection system (see Figure F.4(b))
Mouse	Participant was unable to use a mouse or touchpad due to his degree of physical limitations, however, was able to control his notebook's mouse through an eye-gaze detection system (see Figure F.4(a))
Multitouch	Participant was unable to perform multitouch gestures, however added that he would be able to use, with some difficulty, a touch screen placed on his lap.
Speech (European Portuguese)	Due to time constraints the participant was unable to try speech recognition in this session, however, added that he has previously used ASR systems with unfavourable results in open space environments.
Tablet PC Stylus	N/A
Touch Screen (Smartphone)	Participant was unable to adequately grip the smartphone, however, when fixed to a table surface, was able to perform some drag gestures and touch icons, although with some difficulties (see Figure F.5(a)). Participant added that he would be able to interact with more ease should the smartphone's icons be larger. Participant was however capable of using a cellphone's t9 keypad without a problem (see Figure F.5(b)).

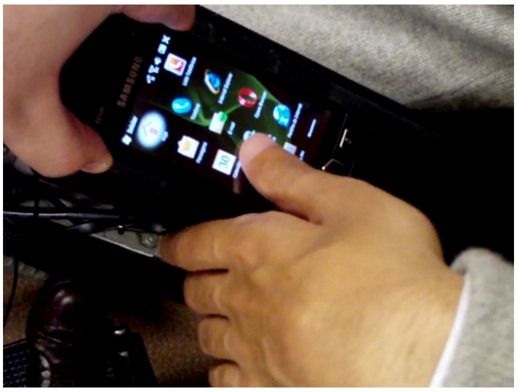
Table F.19: Participant 5 interaction evaluation



(a) Gaze interaction device

(b) Virtual keyboard

Figure F.4: Participant 5 hardware interaction (part one)



(a) smartphone interaction

(b) cellphone t9 keypad interaction

Figure F.5: Participant 5 hardware interaction (part two)

Modality	Results
3D Gesture	Participant managed to correctly use the smartphone's accelerometer.
Keyboard	Participant was only able to write on the keyboard with one finger at any given time due to his degree of physical limitations.
Mouse	Participant used the tablet PC's touchpad with some difficulties.
Multitouch	Participant found it impossible to touch the tablet PC's screen with more than one finger. Participant can, however, easily perform simple drag gestures with only one finger.
Speech (European Portuguese)	Participant can place the headset correctly but with some difficulty. Participant was able to use the ASR test application with ease, however, due to his accent, there were some issues recognizing some words. Participant added that voice interaction is awkward to use and as such, he wouldn't like to use it on a daily basis.
Tablet PC Stylus	Participant managed to use the stylus without a problem, even with a vertically tilted screen.
Touch Screen (Smartphone)	Participant managed to correctly grip the smartphone and use drag gestures, as well as selecting icons on the device's touch screen.

Table F.20: Participant 6 interaction evaluation

Modality	Results
3D Gesture	Participant managed to correctly use the smartphone's accelerometer.

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Modality	Results
Keyboard	Participant managed to type on the keyboard, using both hands, without a problem.
Mouse	Participant managed to use the computer's mouse without any issues.
Multitouch	Participant considers multitouch gestures easy to do.
Speech (European Portuguese)	Participant can place the headset correctly and with ease. Participant finds, however, that currently available European Portuguese ASR engines aren't stable enough to be properly used.
Tablet PC Stylus	Participant managed to use the stylus without a problem.
Touch Screen (Smartphone)	Participant managed to correctly grip and use the smartphone.

Table F.21: Participant 7 interaction evaluation

Modality	Results
3D Gesture	Participant managed to correctly use the smartphone's accelerometer.
Keyboard	Participant managed to type on the keyboard, using both hands, without a problem.
Mouse	Participant managed to use the computer's mouse without any issues.
Multitouch	Participant considers multitouch gestures easy to do.
Speech (European Portuguese)	Participant can place the headset correctly and with ease.
Tablet PC Stylus	Participant managed to use the stylus without a problem.
Touch Screen (Smartphone)	Participant managed to correctly grip and use the smartphone.

Table F.22: Participant 8 interaction evaluation

Modality	Results
3D Gesture	Participant managed to grip the smartphone with some difficulty (see Figure F.7(a)). After managing to grip the smartphone, the participant was able to correctly use the *Dice Game*. Participant had some difficulty using the accelerometer in more complex games like *Resco Snake*.
Keyboard	Participant managed to write with some difficulty using only one finger at a time. Participant found it very hard to use two and three key combinations.
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Modality	Results
Mouse	Participant used the tablet PC's touchpad, finding it easier to use that a regular mouse.
Multitouch	Participant was unable to properly simulate multitouch gestures. Participant finds, however, that single finger gestures, on a large surface, are easy to perform.
Speech (European Portuguese)	Participant can place the headset correctly and with ease. Participant managed to use the evaluation ASR application with ease.
Tablet PC Stylus	Participant managed to use the stylus correctly and with ease (see Figure F.6). Participant tried writing with the screen in a vertical position and horizontally, finding it easier to use a horizontally placed screen. Participant added that, due to his condition, it would be easier to write with a stylus, using handwrite recognition, than with a keyboard.
Touch Screen (Smartphone)	Participant managed to use the smartphone after gripping it, however, found that, due to small icons, it was somewhat difficult to precisely select menu icons (see Figure F.7(b)).

Table F.23: Participant 9 interaction evaluation

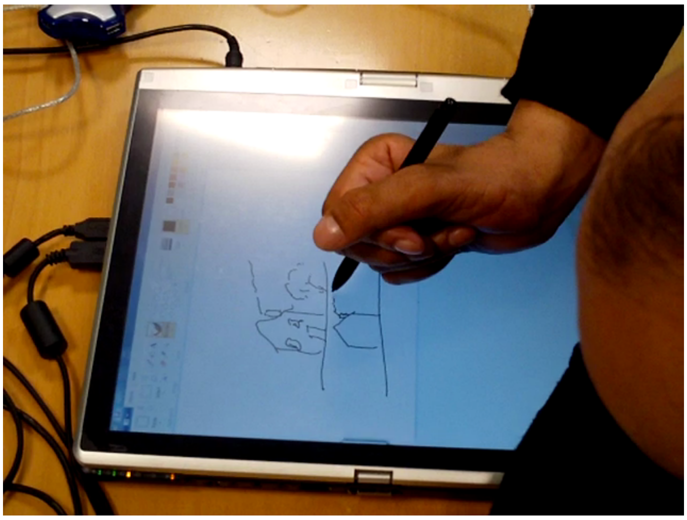

Figure F.6: Participant 9 stylus interaction

Modality	Results
3D Gesture	Participant managed to correctly use the smartphone's accelerometer.
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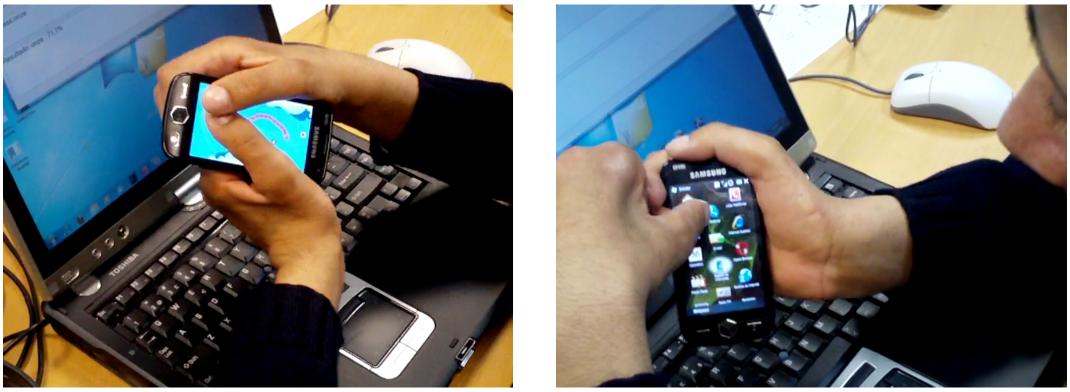

(a) smartphone grip (b) smartphone interaction

Figure F.7: Participant 9 smartphone interaction

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Modality	Results
Keyboard	Participant managed to type on the keyboard, using both hands, without a problem.
Mouse	Participant managed to use the computer's mouse without any issues.
Multitouch	Participant considers multitouch gestures easy to do.
Speech (European Portuguese)	Participant can place the headset correctly and with ease. Participant managed to use the test ASR application with ease. Participant also managed to use Windows's Speech Recognition engine in command & control mode with great ease (participant speaks English fluently), finding it an interesting way to interact with Windows.
Tablet PC Stylus	Participant managed to use the stylus without a problem. Participant finds, however, that handwriting wouldn't be very useful in his daily activities. Participant found that it's easier to use a vertically tilted screen.
Touch Screen (Smartphone)	Participant managed to correctly grip and use the smartphone.

Table F.24: Participant 10 interaction evaluation

Modality	Results
3D Gesture	Participant managed to correctly use the smartphone's accelerometer.
Keyboard	Participant was able to write with two fingers at any given time (see Figure F.8), using sticky keys to aid him with key combinations.

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Modality	Results
Mouse	Participant was able to correctly use the mouse with both his hands simultaneously.
Multitouch	N/A
Speech (European Portuguese)	Participant can place the headset correctly, however, with some difficulties. Participant finds it easier to place an earpiece than a headset. Participant had no issues using the ASR engine and expressed great interest in using ASR primarily in dictation mode and secondarily in command & control mode.
Tablet PC Stylus	Participant was unable to properly use the stylus with a vertically placed screen. By tilting the screen to a horizontal position or even with some inclination, he was able to use the stylus, however, with some issues regarding incorrect handwrite recognition.
Touch Screen (Smartphone)	Participant was able to hold the smartphone with some difficulties. Dragging gestures were very hard to do. Participant was, however, able to select items on the smartphone's menu with some difficulty, adding that icons should be larger and not require such precise motion.

Table F.25: Participant 11 interaction evaluation

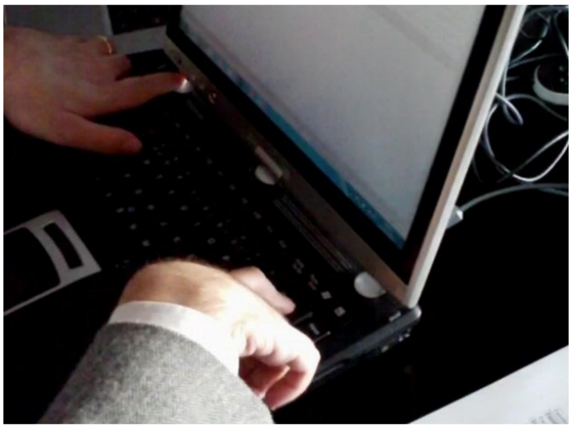

Figure F.8: Participant 11 keyboard interaction

The following table shows statistical results based on the results from question 1 of the questionnaire available in Table 3.4. Participant by participant answers can be seen in detail on Appendix A, section A.3.2.

Participant		1. a) (Computer touch screen)	1. b) (Voice recognition)	1. c) (Smart-phone touch screen)	1. d) (Smart-phone accelerometer)
Participant 1		2	6	1	1
Participant 2		5	6	4	3
Participant 3		N/A	N/A	N/A	N/A
Participant 4		N/A	N/A	N/A	N/A
Participant 5		3	4	4	1
Participant 6		5	5	5	5
Participant 7		6	5	6	6
Participant 8		4	5	5	3
Participant 9		4	5	5	3
Participant 10		4	6	5	5
Participant 11		3	5	3	4
Mean		4.00 (Medium)	5.22 (Easy)	4.11 (Medium)	3.44 (Hard)
Std. dev.		1.22	0.67	1.54	1.74
Paraplegic	**Mean**	4.67 (Medium)	5.33 (Easy)	5.33 (Easy)	4.67 (Easy)
	Std. dev.	1.15	0.58	0.58	1.53
Quadriplegic	Mean	3.67	5.17	3.50	2.83
	Std. dev.	1.21	0.75	1.52	1.60

Table F.26: Hardware modality questionnaire results table (statistical values)

F.4 Detailed Usability Evaluation Results

F.4.1 Profile Editing

Participant	Researcher Observations	Participant's opinions
Participant 5	Participant resorted only to voice control due to his hand and arm motion limitations	Participant found the UI and modalities easy to use
Participant 7	Participant resorted to voice command and control and typed using the physical keyboard Participant had no issues dealing with the UI and modalities	Participant found the UI and modalities easy to use Participant admitted to use the keyboard more than voice due to his voice projection issues, which complicated speech interaction
Participant 8	Participant had some initial difficulties finding how to select a social media service After some initial guidance, the participant was able to complete the task on her own	Participant believes that her issues were derived from never having used the service before Participant found the modalities easy to use. Participant preferred to use touch to select UI fields and the physical keyboard to type text, as she's more used to these modalities.
Participant 9	Participant didn't have significant issues using the UI or the selected modalities Participant evidenced some proficiency in using social media services as no help was needed	Participant found the UI to be easy to use Participant preferred to use the on-screen virtual keyboard and touch to fill form data and control the application, as he finds speech awkward to use
Participant 10	Participant didn't have significant issues using the UI or the selected modalities Participant also evidenced some proficiency in using social media services as no help was needed	Participant found the UI to be easy to use Participant preferred to use the physical keyboard and touch to fill form data and control the application, as he found these modalities more natural to use

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Participant	**Researcher Observations**	**Participant's opinions**

Table F.27: Profile Editing evaluation results

F.4.2 Contact Management

Participant	**Researcher Observations**	**Participant's opinions**
Participant 5	Participant resorted only to voice control due to his hand and arm motion limitations Due to model limitations, dictation mode didn't work very well with some contact names	Participant found the UI and modalities easy to use Participant found dictation mode to be somewhat problematic
Participant 7	Participant resorted to voice command and control and typed using the physical keyboard Participant had no issues dealing with the UI and modalities	Participant found the UI and modalities easy to use Participant admitted to use the keyboard more than voice due to his voice projection issues, which complicated speech interaction
Participant 8	Participant had some initial difficulties finding how to operate the UI, due to rarely using these types of services After some initial guidance, the participant was able to complete the task on her own	Participant didn't enjoy dictation mode as much as the other modalities in this task Participant preferred to use touch to select UI fields and the physical keyboard to type text, as she's more used to these modalities.
Participant 9	Participant had some initial difficulties finding how the application's UI work flow was organized After being given some hints was able to complete the task successfully.	Participant preferred to use the virtual keyboard and touch to complete the task as he's not very keen on using speech interaction
Participant 10	Participant didn't have significant issues using the UI or the selected modalities	Participant found the UI to be easy to use
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Participant	**Researcher Observations**	**Participant's opinions**
	Participant also evidenced some proficiency in using social media services as no help was needed	Participant preferred to use the physical keyboard and touch to fill form data and control the application, as he found these modalities more natural to use

Table F.28: Contact Management evaluation results

F.4.3 Messages

Participant	Researcher Observations	Participant's opinions
Participant 5	Participant resorted only to voice control due to his hand and arm motion limitations Participant found dictation support to work better than in the previous task, and as such used it with success to complete the task Participant resorted to voice control to input special characters such as the euro symbol, without any issues	Participant found the UI and modalities easy to use
Participant 7	Participant resorted to voice command and control and dictation, using the physical keyboard when text dictation didn't work as expected Participant had no significant issues dealing with the UI Participant resorted to the physical keyboard to input special characters such as the euro symbol, without any issues	Participant found the UI overall easy to use As with previous tasks, participant found it somewhat harder to use voice than other modalities due to his voice projection issues Added that it was due to personal preference and force of habit
Participant 8	Participant had some initial difficulties finding how to launch the message image viewer prompt After some initial guidance, the participant was able to complete the task on her own	As with other tasks, participant didn't use voice C&C and dictation due to her voice projection limitations
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Participant	Researcher Observations	Participant's opinions
	Participant resorted to the physical keyboard to input special characters such as the euro symbol, without any issues	Added that it was due to force of habit
Participant 9	Participant had some initial difficulties finding how to launch the message image viewer prompt	Participant preferred to use the virtual keyboard and touch to complete the task after trying voice C&C and dictation, as he found that dictation was somewhat frustrating to use on longer sentences
	Participant resorted to the special character sidebar to input symbols such as the euro, without any issues	Added that it would be preferable if the bar would actually pop out of the virtual keyboard instead of being a separate component all-together
	Participant took longer to complete the task as he hesitated a bit and started sending a private message instead of a status update (Tweet)	
Participant 10	Participant found it hard to determine how to launch the message image viewer prompt, and as such, required some help.	
	Participant preferred to use touch and the physical keyboard as his main interaction modalities, however, when in doubt about how to perform a task, resorted to speech interaction	
	Participant resorted to the physical keyboard to input special characters such as the euro symbol, without any issues	

Table F.29: Message evaluation results

F.4.4 Search

Participant	Researcher Observations	Participant's opinions
Participant 5	Participant resorted only to voice control due to his hand and arm motion limitations	Participant found the UI and modalities easy to use
	Participant found dictation support to work very well, and as such used it with success to complete the task	

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Participant	**Researcher Observations**	**Participant's opinions**
	Participant had some initial issues dealing with the search flow, but after some trial and error was able to use it without any problems	Participant enjoyed the voice control features of the video player
Participant 7	Participant resorted mainly to touch and the physical keyboard due to his voice issues	Participant found the UI overall easy to use As with previous tasks, participant found it somewhat harder to use voice than other modalities due to his voice projection issues
Participant 8	Participant wasn't very familiarized with the video playback features, but after some trial and error was able to control the player	As with other tasks, participant didn't use voice C&C and dictation due to her voice projection limitations
Participant 9	Participant had no problems using the search and video playback features	Participant preferred to use the virtual keyboard and touch to complete the task, as he in previous tasks that dictation was somewhat frustrating to use on more complex entries Participant found video playback control easier to accomplish with speech C&C rather than with touch due to the YouTube player's small UI controls.
Participant 10	Participant had no problems dealing with the search and video playback features Participant preferred to use touch and the physical keyboard as his main interaction modalities, however, resorted to voice C&C when controlling video playback, due to the small controls supplied by the YouTube video player	Participant noted, however, that he would like to have video category support while search to better filter results

Table F.30: Search evaluation results

F.4.5 Audio-Visual

Participant	**Researcher Observations**	**Participant's opinions**
Participant 5	Participant resorted only to voice control due to his hand and arm motion limitations	Participant found the UI and modalities easy to use
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Participant	**Researcher Observations**	**Participant's opinions**
	Participant found dictation support to work well, and as such used it with success to complete the task Participant was unable to use multi-touch at all, while viewing photos in this alternative mode, as can be seen in Figure 7.6(a)	Participant added that he believes he would be able to use multitouch if wearing gloves with attached capacitive stylus
Participant 7	Participant resorted mainly to touch and the physical keyboard due to his voice issues Participant was able to use multi-touch without any issues Participant tried to use dictation to fill a video add form, with unfavourable results Participant successfully used a combination of voice C&C and touch to interact with the photo and video albums' UI	Participant found the UI overall easy to use
Participant 8	Participant was able to use the UI without any significant issues Participant was able to use multi-touch without any issues	As with other tasks, participant didn't use voice C&C and dictation due to her voice projection limitations Participant found the overall audio-visual section easy to use
Participant 9	Participant had no issues dealing with photo and video albums while in regular mode, using touch and the virtual keyboard as his main modalities Participant was able to use the multi-touch canvas to perform simple touch actions, however, was unable to use multi-touch at all, as can be seen in Figure 7.6(b)	Participant found the overall UI easy to use
Participant 10	Participant had no problems dealing with the album management features or with multi-touch capabilities Participant preferred to use touch and the physical keyboard as his main interaction modalities, however, resorted to voice C&C when in doubt about how to perform a specific task	Participant found the UI intuitive to use

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Participant	**Researcher Observations**	**Participant's opinions**

Table F.31: Audio-Visual evaluation results

F.4.6 Messages on a mobile platform

Participant	**Researcher Observations**	**Participant's opinions**
Participant 5	Participant was able to use the smartphone's touch screen when placed horizontally on a fixed surface, as can be seen in Figure 7.8(b) Participant found speech control to work well, however, would like to have dictation support on the platform to allow an easier interaction Participant had some initial issues dealing with the smaller UI components such as some buttons, however, able to operate the device with his thumb after some time Participant was unable to use the device's accelerometer accessible features such as list scrolling, due to his inability to get a proper grip of the device	Participant found the UI easy to use, however, initially found the screen required too much strength to operate, requiring some getting used to
Participant 7	Participant was able to use the device's touch, speech and accelerometer modalities without any issues	Participant found the UI and modalities easy to use
Participant 8	Participant was able to use the UI without any significant issues Participant was able to use all other modalities without any problems	As with previous tasks, the participant found it hard to use the device's voice capabilities Participant found it interesting to combine the device's accelerometer and touch capabilities in a complementary way
Participant 9	Participant had no issues dealing with speech interaction, however, found it hard to use the device's touch screen, as it required too much pressure to react, as well as the device's accelerometer, as it was very hard to get a proper grip of the device	
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Participant	**Researcher Observations**	**Participant's opinions**
	Participant was able to select with some precision all UI controls, be they larger or smaller, however, as noted previously, the strength required for the touch screen to react was somewhat steep	
Participant 10	Participant had no major issues dealing with the UI and modalities Participant was able to use all modalities, including speech, while balancing the usage of these modalities during the task	Participant, however, found some of the components to be harder to use than the desktop's due to the size of them

Table F.32: Mobile Messaging evaluation results